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CRITICAL DESIGN REVIEW UH-1N HELICOPTER RESCUE HOIST. (U)
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MICHAEL H. REAGAN
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AERONAUTICAL SYSTEMS DIVISION
AIR FORCE SYSTEMS COMMAND
WRIGHT-PATTERSON AIR FORCE BASE, OHIO

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FOREWORD

As a result of a series of incidents, and one personal injury accident, involving the UH-1N rescue hoist, an in-house engineering effort was initiated in August 1972 to perform a Critical Design Review (CDR) that would re-examine design and operating characteristics of the hoist. Particular emphasis was given to any design area that might create a safety hazard for the rescuee. This CDR was generally comprised of engineering analysis with flight and laboratory testing which considered past and projected field operating conditions. The following personnel served as members of the Deputy for Engineering Design Review Team and prepared this report:

Mr M. Reagan - Team Leader
Mr P. Eodice - Reviewer of Aircraft Interface
Mr D. Day - Reviewer of Mechanical Design
Mr J. Strayer - Reviewer of Mechanical Design
Mr D. Gilbert - Reviewer of Electrical Design
Mr C. Blake - Reviewer of Static Discharge Problem
Mr E. Rieck - Reviewer of Human Factors
Mr P. Smith - Reviewer of Wire Rope Application
Mr H. Pollack - Reviewer of Wire Rope Application

This technical report presents the findings and recommendations resulting from the design review. The review covers work conducted from August 1972 through January 1973.

This technical report has been reviewed and is approved:

John Ostrominski
JOHN OSTROMINSKI, Lt Colonel, USAF
Director, Crew and AGE Engineering

Paul E. Beck
PAUL E. BECK
Technical Director
Crew and AGE Engineering

SUMMARY

This design review was directed at determining adequacy of the UH-1N rescue hoist subsystem and, to an extent, its individual components. Also included was the determination and evaluation of modifications and operational limitations required for safe, reliable future operations. The detailed design review covered the following specific areas: Design analysis for overall subsystem safety and reliability, accelerated testing for interim training clearance, test under laboratory conditions, flight test, and separate wire rope test and evaluation.

From results of the design review it was determined that the limit switch assembly (up limit switch), which stops cable travel, is subject to malfunction. A malfunction, or misadjustment, in this area can induce loads up to 3,000 pounds on a cable which is nominally rated at 3,300 pounds. It was the opinion of the review team that two previous incidents in the field had been caused by this malfunction. Another serious condition exists in the cable storage drum which is driven through an adjustable slip clutch. This semi-exposed clutch slips excessively and induces fouling and subsequent cable failure when contaminated with fluid such as oil or water. Structure of the secondary capstan was found to be subject to early fatigue in one test case, and displacement of assembled components in another case. This review found that the majority of cable fatigue or overload failures occur without prior warning (visible exterior damage). To correct these critical deficiencies, the team recommended complete redesign of the up limit switch, incorporation of a clutch seal, and reconfiguration of the secondary capstan into a high strength steel, one piece unit. In addition, a cable replacement and hoist overhaul schedule was recommended. Other design deficiencies in the electro-mechanical system were identified but were of a considerably less critical nature. Design corrections in these areas were also recommended.

Structural analysis of the hoist, based on actual flight test loads, indicates that the primary structure is satisfactory. Questionable details of design were encountered and corrective measures were recommended.

The electrical subsystem was analyzed and, in some cases, tested under this CDR. The only critical failure mode found was a guillotine switch assembly that was susceptible to inadvertent manual actuation. A corrective configuration change was recommended.

Human factors were also considered in the design review. No critical shortcomings were identified and the overall design, in this category, was considered satisfactory. Technical orders were also examined as a part of this review area. Recommendations pertain to coverage of corrective design changes and a warning note concerning hoist installation in aircraft.

It was found that forces, caused by a malfunctioning up limit switch, could be appreciably reduced by incorporating compressible plastic foam between the hook assembly and boom. The review team felt that this shock absorbing device would be the key to granting interim clearance at Homestead AFB and Fairchild AFB.

Overall conclusions of the design review team are that: The hoist, in its present configuration, is not suitable for unlimited rescue and training operations; the hoist can be cleared for normal operation after incorporation of critical (primary) design changes and procedural changes related to maintenance; the Homestead AFB interim clearance can be continued; a separate, interim clearance can be safely granted to Fairchild AFB with very minimum modification, but with closely controlled operating procedures.

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SECTION I

INTRODUCTION

In 1965 the Army, for the purpose of expanding their mission capabilities, procured from Bell Helicopter Company (BHC) an internal rescue hoist for use in a rescue role. Since the UH-1 helicopter was a diversified machine capable of performing numerous missions, the hoist had to be portable and lightweight. The winch portion of the hoist was qualified by Breeze Corporation and satisfactorily completed a 1500 cycle endurance test, in addition to meeting other environmental test requirements. The complete hoist assembly, including the boom and actuator, were field evaluated by the Army and found satisfactory.

In 1967 the hoist was introduced into the USAF inventory by ECP action as installed equipment on the TH-1F helicopter delivered to Sheppard AFB to support pilot/crew training. As part of the qualification effort, the winch was subjected to another 1500 cycle endurance test by Breeze. Later the hoist was used on the TAC Special Operating Force (SOF) configured UH-1P helicopters deployed to SEA. With the development and procurement of the UH-1N helicopter for this same SOF organization, additional hoists were procured in response to a firm SOF request. Although only nine hoists were involved, all 79 UH-1Ns were configured to accept the hoist.

In May 1970, MAC became a user of the aircraft and indicated their intent to utilize the aircraft with its auxiliary hoist kit to support the USAF Survival School training mission at Fairchild AFB. Based on the mission profile provided, and the predicted usage rate of approximately 20,000 pick-ups per year, a study was made to determine if the hoist was capable of supporting this mission. A review of the Breeze qualification effort for the winch showed that the two 1500 cycle endurance tests performed (one for Army, one for USAF) were much more severe than the Aerospace Rescue and Recovery Service (ARRS) mission profile. In addition, no problems were being reported from Sheppard AFB or TAC/SOF concerning their operations with the hoist. As a result of these findings, MAC was advised that the UH-1N hoist would meet their mission requirements.

Since ARRS has been in operation, six apparently unrelated severed cable incidents have been encountered with the hoist at the survival school training sites at Fairchild AFB and Homestead AFB. Four of these failures occurred with students on the hoist. On each occasion, ARRS restricted the use of the hoist to only life or death missions until the cause of the failure was determined and corrected. After the first failure, a test program was conducted at Breeze using the Fairchild AFB mission profile. A total of 2500 cycles was satisfactorily achieved with no significant discrepancies noted. This testing appeared to reaffirm the previous position that the hoist, with the addition of several changes resulting from the test, was still a satisfactory piece of support equipment. Also, no hoist problems were being reported from any other location, which tended to support the theory that the ARRS incident was an isolated failure. With

the necessary modifications incorporated, the next two severed cable incidents were found to have been caused by either a maintenance or environmental problem. Up until that time, each cable failure had been caused by some malfunction within the hoist and corrective action taken to prevent its recurrence. The last two unexplained cable failures, however, generated extreme concern that there were basic design problems with the hoist and that the survival school operation was, on an accelerated basis, revealing these deficiencies. It was at this time that a decision was made to restrict the use of the hoist until a thorough review of the program could be completed. The investigation surfaced many unanswered questions and it was determined that the only feasible approach open was to conduct an in-house Critical Design Review of the hoist.

A detailed, chronological expansion of the above background material is included as Appendix VII to this report.

SECTION II

ELECTRO-MECHANICAL ANALYSIS

1. Purpose - The purpose of this section of the CDR is to review each design area of the hoist assembly with a view toward identifying and analyzing potential failure modes and their effect on hoist performance and safety. Preliminary design considerations pointed toward reducing or eliminating the potential failures are also treated.

2. Configuration Particulars - The electro-mechanical configuration of the Bell Helicopter Company and Breeze Corporation manufactured rescue hoist is typical of those designs where lightweight and compact size are primary design considerations. Overall configuration of the hoist, with itemized sub-assemblies, is shown in Fig 1 and referred to by item number in this section. The following are configuration and rated performance particulars for the hoist:

a. Mast/Boom Assembly - This assembly consists of a vertical tube mast attached to the floor and ceiling of the aircraft (Fig 1, item 13), a boom (Fig 1, item 7) which attaches to the mast and extends in a horizontal direction, and a linear actuator that rotates the mast and boom between an outboard operating position and an inboard storage position. This action is also used to rotate a suspended rescuee into the aircraft. Cable is routed from the winch (Fig 1, item 24) up along the mast and out along the boom via a free running pulley at the boom base and a powered traction sheave at the boom outboard end.

b. Electric Control Box - The control box (Fig 1, item 16) is the central control unit for the entire hoist subsystem. It routes commands from the hoist operator's position (via control pendant) or the pilot's position (via panel mounted controls) to other hoist components. A number of relays form the essence of the control routing method, while an electronic "chopper" circuit controls motor speed by varying the time duration between constant shape, square wave pulses.

c. Winch Assembly - This unit (Fig 1, item 24), weighing 52 pounds, is powered by 28 volt DC from the aircraft. It pays out and retracts 256 feet of wire rope (cable) with 600-pound maximum load at speeds up to 100 feet per minute.

d. Winch Motor - The motor is 28-volt DC, at 110 amps maximum, with 8,500 rpm (no load). It has an integral electro-mechanical brake which actuates when electric power is interrupted. The motor is compound wound, is reversible, and weighs 10.75 pounds.

e. Winch Capstan Drive - This assembly of two (primary and secondary) capstans is driven by the winch motor through a planatary gear train and load brake assembly. Cable is laced around the primary and secondary capstans in a figure eight fashion and is thus powered in or out by capstan rotation.

f. Winch Storage Drum - After being powered through the capstan drive, the cable passes through a level wind assembly and is wound on the storage drum under relatively low tension (50 to 75 pounds). Drive to the storage drum is through a slip clutch that maintains tension and compensates for required difference in rpm between the capstan and storage drum as cable builds up on the drum.

g. Control Pendant - The hand held control pendant (Fig 1, item 26) incorporates three switches - one for controlling motor speed and direction, one for the hoist operator's intercom, and one for rotating the hoist assembly.

h. Boom Up Limit Switch Assembly - This assembly (Fig 1, items 29 and 30) is incorporated at the outboard end of the boom. Its function is to cut primary power to the motor, through a control box relay. The limit switch is actuated when the retrieved hook contacts a trigger mechanism on the boom.

i. Guillotine - The guillotine is pyrotechnically powered and electrically actuated from a switch mounted on the control box and on the pilot's console. It is used to sever the cable when a cable snag is jeopardizing the aircraft.

j. Traction Sheave - The traction sheave (Fig 1, item 1) functions to aid in lowering the hoist cable and prevent cable snarls in the boom by maintaining a constant 5-7 pound tension on the cable as it is being payed out of the hoist.

k. Cable - The hoist contains 256 feet of spin resistant, 3/16 inch diameter, 19 x 7 (19 strands of 7 wires each) cable.

3. Design Analysis - The following is a narrative report covering this CDR's analysis of all design areas comprising the hoist. References herein are made to figures, numbered items therein, and appendices.

a. Hoist Structure - A structural analysis was conducted by Aeronautical Systems Division, Directorate of Airframe Engineering. This analysis covered the complete hoist assembly with the exception of cable and internal winch components. Based on loads demonstrated in flight testing (App III), the hoist was determined to be structurally adequate. There are, however, some noteworthy characteristics of the attaching structure that are discussed as follows:

(1) Hoist Quick Attach Fittings - The hoist is installed via quick attach fittings on both ends of the mast (Fig 1, items 10 and 22). These fittings attach to "seat stud" type fittings (Fig 1, items 9 and 19) in the aircraft ceiling and floor. These fittings are sometimes damaged in handling. Examination under this CDR revealed no damage that would cause the hoist to inadvertently disconnect. However, as a precautionary measure, a hoist should never be installed and used when either fitting cannot be manipulated to the snap-to-lock position.

(2) Ceiling Studs - Verified reports by the user have been received to the effect that the ceiling studs (Fig 1, item 9) are loosened by continuous use. These studs are retained in ceiling mounted cups (Fig 1, item 37) by a castellated nut with washer and cotter pin. Since the nut cannot appreciably loosen, then loosening of the connection is attributed to wear in the washer and/or cup when the stud rotates. Rotational forces are induced when the mast/boom assembly is rotated in and out of the aircraft. Complete correction of this condition could be accomplished by incorporating anti-friction bearings in the mast ends. This would be an extensive hoist design change. A workable compromise might be the substitution of a larger diameter flat washer between the nut and cup. This would all but eliminate the possibility of wearing through and failing the cup, and additionally, the ceiling cups that are presently riveted in place could be bolted to facilitate initial installation and subsequent inspection. Feasibility of this change, plus other alternatives, should be investigated.

(3) Boom-to-Mast Connection - Overall structure involved in this connection has been analyzed and is considered structurally sound. No indication of overload was observed or recorded during electro-mechanical and flight testing (test report App III and V). There are, however, bushings in the boom retaining pin hole (Fig 1, item 14) that fall out and are frequently lost. A method for retaining these bushings in place would improve performance from an installation and maintenance standpoint.

(4) Winch-to-Mast Connection - The brackets which facilitate mounting the winch on the vertical mast have been analyzed and found to be structurally adequate. It was determined, however, that a potential cable snag area is formed by a hex head bolt in the top mounting bracket (Fig 2). This condition can be corrected by substitution of an oval head machine screw.

(5) Winch Outer Structure - The winch exterior structure is comprised largely of aluminum castings which are often damaged during the frequent installation and removal of this portable hoist. Breeze Corp has reported that an appreciable number of winches show exterior damage (cracks and deep gouges) when they are received for overhaul. In one case, a part of the level wind assembly (constructed of heat treated steel) was bent to the point where the follower would not move. This caused failure in the gear drive system. Had this condition gone unobserved, and not corrected, this cable could have failed during operation. This condition could be alleviated appreciably by incorporation of a tubular steel framework around the winch. The framework would attach to the mast and could also serve as a handhold while carrying and installing the hoist.

(6) Traction Sheave - The traction sheave is an exposed assembly that is critical to safe hoist performance. A tubular steel guard is also applicable in this case.

b. Winch Assembly - For the sake of this discussion, the winch is considered to be basic structure, electric motor, gearing, capstan drive, level wind, storage drum, and directly attached electric components. Only those areas where irregularities or failures occurred, or where failure causing design deficiencies are suspected, will be discussed herein.

(1) Oil Leaks - Oil leaks were encountered and the source identified in two areas:

(a) Gear Case Gasket - The gasket under the main gear case cover leaked oil after repeated test cycling. This was due to unrealistically high oil temperatures (230°F as compared to a 200°F maximum operating oil temperature) generated by accelerated interim clearance cable testing (App II). A check at Homestead AFB revealed that they had never experienced oil leaks or excessive overflow through the breather vent. This indicates that their operating temperature stayed well below 200°F. Later in the cycling, however, the storage drum clutch began to slip excessively and cause cable spooling. This condition would have resulted in cable failure. Examination of the clutch revealed that oil had caused the clutch slippage but no oil path from the clutch to the gear box was found. A new, dry clutch and oil seal were installed and the cycling continued. This same hoist was operated through additional testing (at least four times more cycling than prior to clutch slippage) and the seal leaked again. However, no slippage or oil contamination in the clutch was experienced. In addition, special care was taken to prevent oil or fluid spillage (as when adding oil) on the clutch. It was then concluded that clutch contamination and subsequent slippage had been caused by either spilling oil during servicing or by dumping oil from the open gear case during installation of instrumentation which requires various positionings of the hoist. The potential problem of clutch contamination and slippage is further treated under a separate heading.

(b) Motor Shaft Seal - A motor shaft oil seal started to leak after 1,700 cycles in the electro-mechanical testing (App V). This allowed gear oil to enter the motor windings/brushes and resulted in intermittent periods of inadequate or marginal torque. At no time did the suspended load lower inadvertently during the irregularity. Considering this and past field experience, this irregularity is not projected as a future operational problem.

(2) Capstan Drive System - Two CDR winch assemblies experienced malfunctions in the secondary capstan. These malfunctions are summarized as follows and detailed in App V.

(a) Failed Spokes - At 4,000 lift cycles (last 1,400 at 600-pound load) into the cable evaluation portion of the CDR, the secondary capstan spokes failed with resulting cable failure. Suspected cause of the capstan failure was metal fatigue in the cast aluminum spokes. The hoist involved came to the CDR directly out of overhaul. Overhaul records do not record previous hoist use (cycles or hours); however, it was shown that the secondary capstan had never been replaced.

(b) Capstan Rim Slippage - At 1,551 cycles into the electromechanical evaluation testing (51 cycles at 600 pounds load), the cable failed. An exterior inspection of the winch was made and no cause could be determined. A new cable was installed and the cycling continued at 600 pounds load. At 1,771 cycles the cable again failed. Both cables were inspected and it was found that the inner core failed while the outer strands were still intact; i.e., there was no visible indication of damage until final failure. At this point the winch was partially disassembled and it was found that the grooved steel rim had slipped 1/16 inch axially along the cast aluminum capstan body and had forced the cable against the aluminum cable guide (Fig 3). Cable failure was attributed to the binding and pinching action between the rim and bear claw. No definite cause of rim slippage was determined. However, there were three noteworthy, associated conditions. There was a snapping noise in the secondary capstan area which started at about 1,500 cycles. Subsequent inspection revealed that the shrink fit dimensions between the rim and capstan were slightly loose and out of tolerance. Finally, both spoke failure and rim slippage occurred at 600 pounds load.

(c) Corrective Design Change - The in-house review team and Breeze Corp analyzed the failures described in (a) and (b) above. The out-of-tolerance condition was considered a possible cause for the lateral rim slippage but was discounted as a reason for spoke failure. Excessive winch bearing mount deflection was also considered as a potential cause of both the spoke failure and the rim slippage. This consideration was based on the fact that original winch qualification (endurance cycling at high load) was conducted at Breeze Corp with the winch mounted on a relatively massive test fixture. The CDR testing was conducted with the winch mounted on the relatively flexible mast. It was agreed that verification of such a theory would require additional extensive testing. The correction that appeared most promising was incorporation of a steel capstan of heavier section than the present cast aluminum/steel design.

(3) Storage Drum - This rotating drum stores multiple layers of cable applied through a lead screw level wind under tension applied by a slip clutch in the drive system. The following are some observations based on CDR testing and prior field use:

(a) Cable Spooling - When foreign material, such as water or grease, infiltrate the clutch area, the tensioning function of the clutch deteriorates to the point where the cable spools on the storage drum. This spooled cable can, and does, loop over the drum flange and fouls/binds when cable is subsequently payed out. This binding action creates excessive tension which finally severs the cable. Entry of foreign material can be stopped by installing a permanent clutch area seal (Fig 4).

(b) Fouled Clothing - Although not experienced during the CDR, there have been confirmed user reports of clothing being fouled in exposed, moving cable on the drum. This condition could be corrected by

enclosing the drum with a sheet metal cover. A window would have to be incorporated in this cover so that any cable lay irregularities could be observed. It was the consensus of the team that the disadvantages of limited drum visibility would overshadow the protective advantages of the cover.

c. Boom Assembly - For purposes of this discussion, the boom assembly is considered to be boom structure, pulley, traction sheave, guillotine, and up limit switch assembly. These areas are discussed as follows:

(1) Boom Structure - Analysis and test have shown that the boom is structurally adequate.

(2) Pulley - Although smaller than recommended by cable manufacturers for optimum cable life, the inboard boom pulley (Fig 1, item 28) is considered adequate in structure and cable interface. The adequacy is, however, dependent on cable replacement within prescribed intervals. With regard to installing a new cable on the hoist, there is a configuration in this area that has led to a misreeved and subsequently failed cable. The cable guide bolt (Fig 1, item 34) is located so that cable can be reeved over the bolt rather than properly between the bolt and pulley. The potential for misreeving could be greatly reduced by incorporating a spacer to block out the area between the bolt and the mast. The area in question and spacer configuration are schematically depicted in Fig 5.

(3) Traction Sheave - As stated previously, proper functioning of this assembly is important to safe hoist performance and its exposed areas should be protected from handling damage. Due to configuration of the spring loaded roller in this assembly, there is not adequate clearance to thread a cable ball end when installing a new cable. This means that cable must be removed from a new overhauled winch so that the cable end, opposite the ball fitting, can be threaded through the traction sheave assembly. This detail of design does not fall in the category of a potential cause for failure, but is a nuisance factor worthy of simple correction.

(4) Guillotine - The guillotine assembly proper (Fig 1, item 4) is considered adequate. There is, however, a potential problem in its activating switch located on the electric control box. The existing switch and safety cover actuate in the same direction of rotation. This means that a single motion, single direction, manual manipulation could expose and activate the switch. Such a configuration in the present location is susceptible to inadvertent actuation. Incorporating a switch guard (Fig 8) would greatly reduce this hazard.

(5) Limit Switch Assemblies -

(a) Description - The up and the down limit switches stop the hoist when the cable is all the way up or down, respectively. The up limit switch (Fig 1, item 29) is activated when the hook assembly (Fig 1, item 27) contacts the trigger assembly (Fig 1, item 30). The trigger

assembly adjusting bolt (Fig 1, item 33) depresses the limit switch plunger, opening the up mode control box power relay preventing hoist operation in the up mode. The down limit switch is located in the hub of the storage drum. This switch opens the down mode control box power relay when there are three wraps of cable left on the drum. There are three basic failure modes in the assembly which could produce a hazardous effect. These failure modes are discussed **below:**

1. Adjustment - As the adjusting bolt is backed off, the two block force (tension in the cable caused by powering the hook assembly against the boom) becomes progressively higher. This force reaches approximately 3,000 pounds when clearance between the adjusting bolt and switch is such that the hook assembly contacts the rollers (Fig 1, view B) prior to switch activation. Considering that the cable's ultimate strength is 3,300 pounds, failure in the cable can be expected at any time there is a gross misadjustment (manually set or through vibration) or malfunction in this area.

2. Electric Short - If the limit switch shorts in the closed position and plunger activation does not open the series circuit to the motor power relay, two block forces will reach 2,800 pounds. Cable failure in this case will again be imminent.

3. Trigger Deformation - Another potential cause of excessive two block forces is permanent deformation in the trigger structure. Such deformation would allow the bumper assembly to contact the boom mounted rollers prior to limit switch activation.

(b) Production Variation - Inspection of several production hoists has revealed a wide variation in trigger assembly performance characteristics; i.e., two block forces on a properly adjusted trigger are between 60 and 500 pounds. The hoist that generates 500 pounds when properly adjusted is therefore much more critical to slight misadjustment of the bolt.

(c) Corrective Design Change - Considering the above, it is apparent that a rather extensive up limit switch assembly redesign is required to insure near fail safe performance. A design of this type would incorporate full redundant electrical circuitry, would not be adjustable in the field, and would have rugged construction to resist deformation. One such design is schematically depicted in Fig 6.

d. Electric Control Box - This assembly was notably free of irregularity during the CDR testing. There are, however, three areas that must be considered:

(1) Guillotine Switch - The guillotine switch and safety cover are located on the control box top. Rationale for guarding this switch is covered under the boom assembly analysis, para c(4).

(2) Motor Power Relay - In order to accomplish complete redundancy in the up limit switch electrical circuit, an additional power relay must be added. This relay would be a control box part and would be in series with the existing relay that closes the electric motor power circuit.

(3) Actuator Power Relay - During flight test at Bell Helicopter Company a 600-pound test weight was being rotated into the aircraft. During this rotation the weight encountered an obstruction and stalled the actuator. After freeing the weight, subsequent control manipulations failed to cause proper actuator movement. Inspection revealed that the actuator's power relay had failed. This condition could possibly occur during field use. The part failure could be corrected by incorporation of a heavier duty relay and/or a circuit breaker in the power line. Although this is a potential failure mode as related to hoist performance, the potential for field occurrence is considered too low to warrant physical modification of the design. When the actuator fails to actuate, a pip pin can be removed and the boom can be manually rotated.

e. Control Pendant - The control pendant (Fig 1, item 26) is rather complex in design and there have been field reports of intermittent operation in the past. However, analysis and test under this CDR have revealed only three questionable areas. They are:

(1) Switch Boot - The rubber boot switch cover deteriorates through continued usage. Since this boot serves as both a protective cover and spring return for the switch, its failure creates a safety hazard in that the hoist will not stop when manual pressure is removed from the switch. From the CDR testing it is estimated that the rubber boot will last at least 3,000 rescue or training lifts. Since it is apparent when the boot is failing, redesign does not appear necessary.

(2) Cord Bending - Electric cord connections at the pendant and control box are subjected to severe bending during use. The sharp bending causes conductor breaks and intermittent electrical contact. This condition can be corrected by incorporating molded sleeves at both ends of the cord.

(3) Electric Connectors - Cord connectors, P/N PT06E-12-10F and PT06E-12-10S, incorporate brass screws that are threaded into the aluminum cable clamp. Salt and galvanic corrosion cause these screws to "freeze" up in a very short time. When disassembly of the plug is attempted, the brass screws fail in torsional shear. Plated steel screws would alleviate this condition.

f. Hook Assembly - Field experience and CDR testing have shown that the hoist hook can be engaged with the forest penetrator in such a way that the penetrator remains cocked on the hook when load is applied. An anti-cocking device has been designed by Breeze Corp and was effectively used in the Fairchild AFB training operation (Fig 7). This device functions

to assure that, under load, the hook is always axially aligned with the penetrator and thus eliminates adverse bending load in the cable at the ball end connection.

g. Wire Rope (Cable) - A considerable portion of the CDR testing was directed toward evaluating various types (chemical composition and heat treat) of 19 x 7, 3/16 inch diameter cable. In App IV these cables are designated types A, B, C, and D, as follows:

Type A - Military specification cable (MIL-W-83140)

Type B - Non-military specification cable (degreased)

Type C - Proposed military specification cable (MIL-W-83140)

Type D - High strength 3,700-pound non-military specification cable (degreased)

A summary of findings is as follows:

(1) Type A and C cable could withstand 2,000 operating cycles on the UH-1N hoist without appreciable degradation in strength.

(2) Type A and C cable exhibited far superior endurance characteristics.

(3) Type A cable showed less difference in breaking strength caused by cable end rotation.

(4) In the majority of cases, all types partially failed in their inner strands prior to separation. This shows that exterior evidence will only identify impending failure under a very few specialized conditions of overload, misreeving, or mishandling.

4. Static Electricity Discharge - Although not a direct contributor to static electricity generation, the life support role of the hoist intensifies the static discharge problem. ASD/ENVCC conducted an investigation in this area. A report of their findings and recommendations is included in this report as App VI.

5. Human Factors and Technical Manuals - Design and operation of the hoist was reviewed from a human factors standpoint. As a related area, applicable technical manuals were also reviewed. The findings were as follows:

a. Human Factors - General configuration and interface of the hoist with the operator and rescuee were considered acceptable. The following potential aircraft changes, to enhance operator safety, were considered:

(1) Rescue operations are sometimes conducted in driving rain and/or over water. These conditions make the existing cabin floor surface slippery. Non-skid floor covering material (paint or pressure sensitive tape) in the operator's maneuvering area would alleviate this situation.

(2) There are many occasions when the hoist operator must lean out of the aircraft and view the terrain and/or rescuee. Even though he has a safety harness, a handhold strap above the door could be used to advantage.

b. Technical Manual Review - Technical Manual TO 1H-1(U)N-2-1 and Safety Supplement TO 1H-1(U)N-21SS-9 were reviewed. The documents were considered to be essentially adequate for the hoist in its present configuration. Some changes are, however, recommended in Section IV of this report.

SECTION III

CONCLUSIONS

1. In its present configuration, the hoist is not suitable for safe, reliable completion of all assigned missions.

2. When compared to a fixed hoist installation, the portable UH-1N hoist, by its very nature, is considered complex in design and is susceptible to malfunctions induced by continuous handling during installation, removal, and maintenance.

3. To safely accomplish all assigned missions with a high reliability (from a safety standpoint), and with reasonable maintainability, some design and procedural changes must be made. The minimum required design changes, along with procedural changes, are detailed in Section IV.

4. Incorporation of all recommended design changes in Section IV will provide the user with as optimum a configuration as can be practicably obtained.

5. An existing winch of different design cannot be effectively substituted for the UH-1N hoist. Each hoist design examined would, cost effectively, have to be used with the UH-1N boom and mast assembly and would possess many of the same malfunction potentials.

6. An acceptably safe live pick-up training operation can be given interim clearance at Fairchild AFB. Conditions for this clearance are detailed in Section IV.

7. The interim rescue training procedure, developed early in the CDR program, and now employed at Homestead AFB, is considered acceptably safe. However, as a result of additional laboratory tests, it was found that safety and/or economy of the interim training procedure could be improved by implementing some changes related to cable change interval and equipment inspection.

SECTION IV

RECOMMENDATIONS

1. Design Change Recommendations - Design change recommendations herein are listed as primary (required for safe basic operation of the hoist), and secondary (required to improve performance, reliability, and maintainability).

a. Primary Design Change Recommendations -

(1) Hoist Up-Limit Switch - Redesign the hoist up limit switch to provide partial mechanical, and full electrical, redundancy (including the control box power relay), to eliminate field adjustment, and to provide more structural integrity. See Fig 6 for a schematic depiction of design features and Section II for rationale.

(2) Secondary Capstan - Incorporate a steel secondary capstan in the winch to replace the existing aluminum and steel unit (Breeze P/N BL-5164). Configure the grooved surface so that the need for a side spacer (P/N BL-8079) is eliminated.

(3) Storage Drum Clutch Seal - Incorporate a storage drum clutch seal (Fig 4) to prevent entry of foreign material.

(4) Guillotine Switch - Add a guillotine switch guard as generally depicted in Fig 8 to protect against inadvertent operation.

(5) Hour Meter - Incorporate an hour meter to record motor running time. Since the motor operates only during winch movement, a reasonable correlation between time and operating cycles can be made. This information will be vital in scheduling cable replacement and hoist overhaul.

(6) Cable Guide Bolt - Incorporate a spacer to block out the area where a cable can be reeved over the inboard boom pulley guide bolt (Fig 5).

(7) Hook Anti-Cocking Device - Provide hook anti-cocking devices for use with the forest penetrator (Fig 7). This device will reduce an adverse cable loading condition caused by a sharp bend at the ball end fitting.

(8) Pendant Cord - Incorporate a molded sleeve on both ends of the control pendant cord. While making this change, replace the brass connector screws with plated, steel screws.

(9) Upper Winch Mount - Replace the hex head bolt in the upper winch mount with an oval head machine screw to eliminate a pocket for potential cable fouling (Fig 2).

b. Secondary Design Change Recommendations -

(1) Winch and Traction Sheave Guard - Incorporate separate tubular steel guards around the winch and traction sheave for protection and to aid in handling the hoist assembly.

(2) Pilot's Warning Light - Provide a cat eye cover for field installation over the pilot's 20-foot warning light to reduce pilot distraction.

(3) Non-Skid Floor Material - Apply field installed non-skid material (paint or pressure sensitive tape) to the floor in areas where the operator must maneuver.

2. Special Recommendations - Recommendations in this category either require design feasibility study by the contractor or are not directly related to hoist configuration. These recommendations are not presented in order of merit.

a. Ceiling Mount Studs - Users have reported that these studs become loose in service. The contractor should determine whether or not this condition could occur in all mounts and could lead to failure and cause the hoist to detach. If this could reasonably be expected to occur, then thecontractor should propose a cost effective airframe (TCTO type) modification.

b. Winch Mounting - The winch manufacturer considers it a distinct possibility that secondary capstan fatigue failure may be caused by excessive displacement of one winch mount (Fig 9) with respect to the other, and that mast deflection would cause this displacement. With this in view, it is recommended that the contractor investigate the feasibility of incorporating a single "strong back" mount to reduce displacement.

c. Automatic Slow Speed Control - As a backup to the redesigned up-limit switch assembly, the contractor should investigate incorporation of an automatic motor slow down switch that actuates in the last 10 to 20 feet of cable retrieve. This change could simplify design of the new up-limit switch since it would reduce the effect of variations in motor brake performance as these variations relate to cable travel after switch activation.

3. Interim Clearance Recommendations -

a. Fairchild AFB - An interim live rescue training operation should be cleared at Fairchild AFB subject to the following strictly enforced conditions, which should be issued as directives, as appropriate:

(1) All hoist assemblies at Fairchild AFB, plus spare units if deemed necessary, shall be shipped to the manufacturer for overhaul. This will result in zero time hoists for purposes of this clearance. In addition to present overhaul practice, the following shall be included:

(a) All secondary capstan assemblies shall be replaced with new, zero time assemblies of the same design.

(b) Three equally spaced rotational alignment scribe marks shall be made in the capstan assembly paint on each side of the steel rim and aluminum casting. Thus, any rim rotation with respect to the aluminum casting can be detected by examining the alignment of the casting and rim scribes (Fig 10). By having three scribes, one will always be visible.

(2) Temporary guards, which prevent inadvertent cable cut switch actuation, will be designed and fabricated in accordance with MIL STD 1472 by ASD (Fig 8). The guards will be installed on site.

(3) The hook, rubber bumper, handhold ring, and forest penetrator eye bolt shall not be used for the training mission. Instead, a stud/shock absorber configuration (Fig 11) will be utilized. Approximately six inches of forest penetrator/floor clearance is gained. Thus, there should be no reason for contacting the up-limit switch, and extreme care shall be exerted to insure that the up-limit switch is not contacted. These assemblies will be designed and fabricated by ASD. Installation will be accomplished on site.

(4) All hoists shall be equipped with cable in accordance with MIL-W-83140 and this cable shall be replaced every 1,500 cycles, or sooner, if constraints defined herein prevail.

(5) Hoist assemblies shall be overhauled every 3,000 cycles, or sooner, if constraints defined herein prevail.

(6) Extreme care shall be taken to prevent introduction of foreign material (particularly liquids) into the storage drum clutch area. The clutch shall be checked for proper torque at the start of each day's operation. A method of checking this torque without disassembly of the winch will be provided to the user.

(7) Comply with all provisions of TO 1H-1(U)N-2-1 and TO 1H-1(U)N-2-1SS-9 unless in conflict with these limitations. Details covering this area shall be provided prior to granting any clearance.

(8) A cycle is defined as lowering the cable and lifting a student, or as an inspection cycle.

(9) The upper capstan shall be inspected at convenient intervals (not to exceed 100 cycles). This shall be accomplished as follows:

(a) The upper bear claw shall be removed.

(b) The scribes on the upper capstan shall be checked for alignment. If the scratches are more than 1/32" misaligned, the hoist will not be used until the upper capstan is replaced.

(c) The upper capstan shall be checked for axial rim slippage by insuring that there is no paint gap between the sides of the steel rim and the aluminum casting portion of the capstan. If there is any unpainted casting visible at the steel rim (Fig 10), the hoist shall not be used until the upper capstan is replaced with a zero time unit.

(10) The styrofoam shock indicator (green foam) will be checked for dents before and after each training mission and after each cycle. If any foam deformation is present, a new cable shall be installed.

(11) The maximum hoist load shall be 300 pounds (one man).

(12) ASD shall provide detailed instructions for Fairchild AFB covering the interim clearance operation.

b. Homestead AFB - The current live training clearance should be continued at Homestead AFB. To reduce cost, and further reduce risk, the following procedural modifications are recommended:

(1) Increase time between cable replacement from 500 to 1,500 cycles.

(2) Put scribe marks on the secondary capstan at base level in accordance with para 3.a(1)(b) above. Inspect and replace the secondary capstan in accordance with para 3.a(9) above.

4. Procedural Recommendations - The following procedural recommendations (not directly associated with design change) apply to overall clearance of the hoist for its intended mission:

a. Preparation for Shipment - Presently, new or overhauled winches are shipped with the cable installed. This cable must, in turn, be removed prior to winch installation on the hoist. To reduce installation time and effort, the winch should be shipped with accompanying cable.

b. Cost Estimates - Obtain planning cost estimates on primary and secondary changes and on accomplishment of special recommendations.

c. Primary Changes - Accomplish all primary changes.

d. Secondary Changes - Accomplish such secondary changes as are determined to be cost effective.

e. Final Clearance - Clear all UH-1N hoists for their intended use in rescue and training. Many detailed actions will be involved in this clearance. For the purpose of this CDR, however, the following high points are listed:

(1) Bring all hoists in for overhaul and modification. This will put all hoists on a zero time basis.

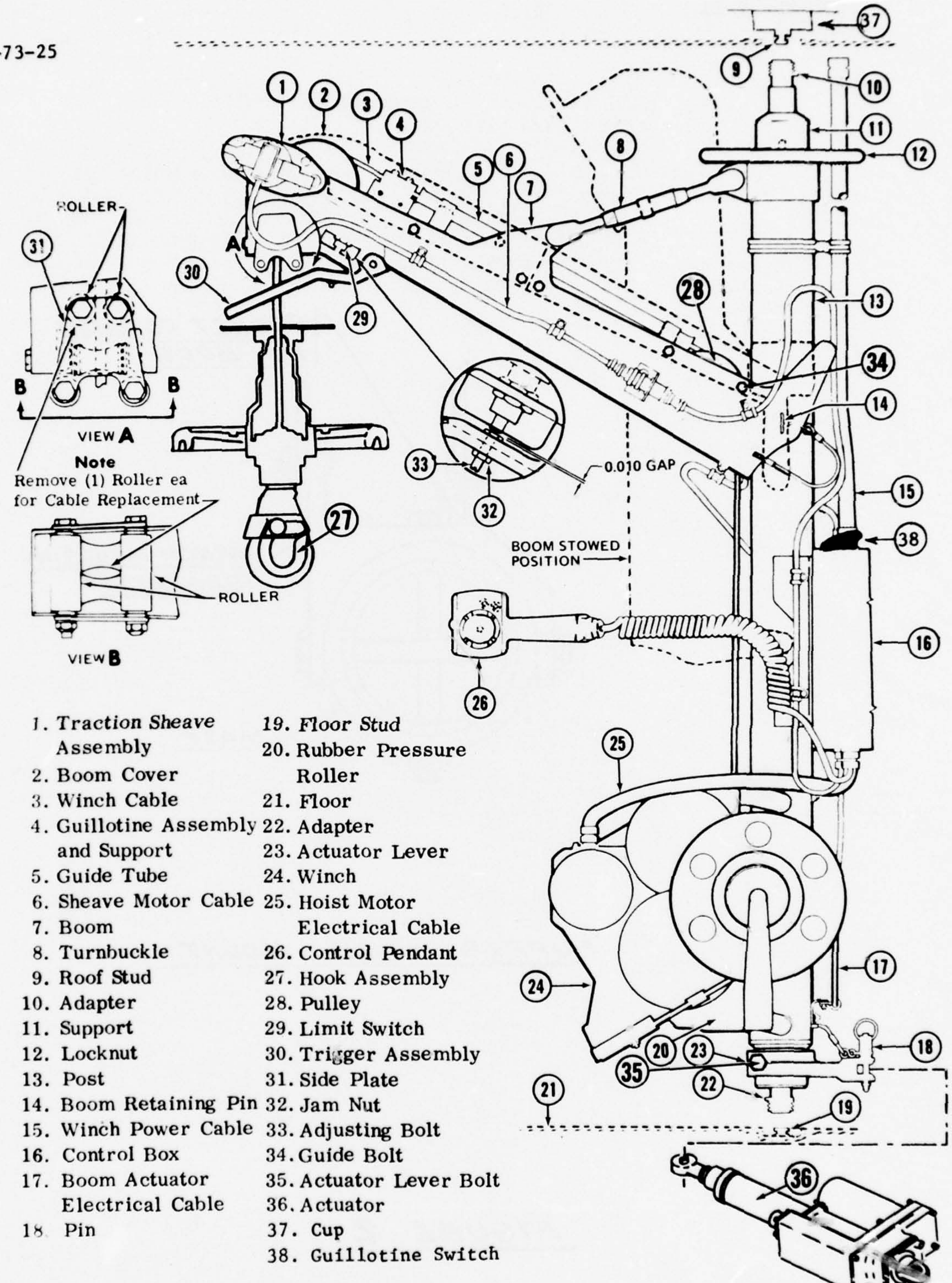
(2) Replace cable every 1,500 lift cycles or hour meter equivalent. Use MIL-W-83140 cable.

(3) Change technical orders to reflect the latest hoist configuration and include applicable procedures covered by this report and those generated/approved later. Of immediate concern is incorporation of the following warning notes:

WARNING: Do not use hoist if ceiling or floor attaching devices cannot be manipulated to the "snap-to-lock" position.

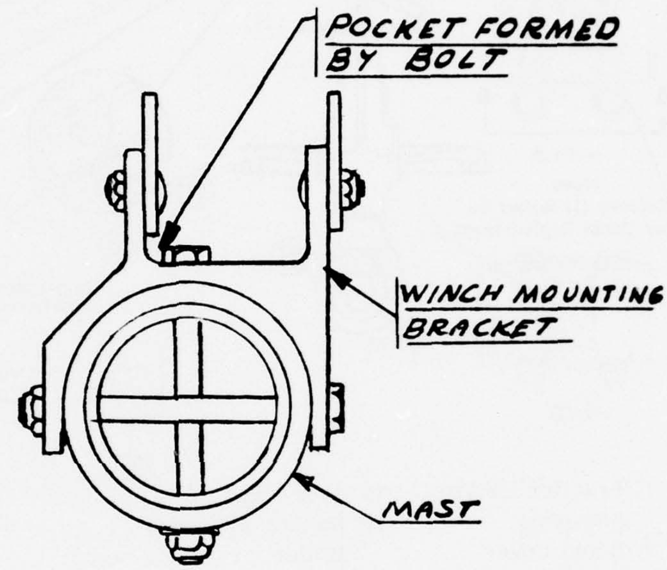
WARNING: Care should be used to insure that no oil or water is introduced into the storage drum clutch area.

WARNING: After winch, pulley, or cable replacement, check cable/cable cutter (guillotine) alignment with 40 lb tension on cable.



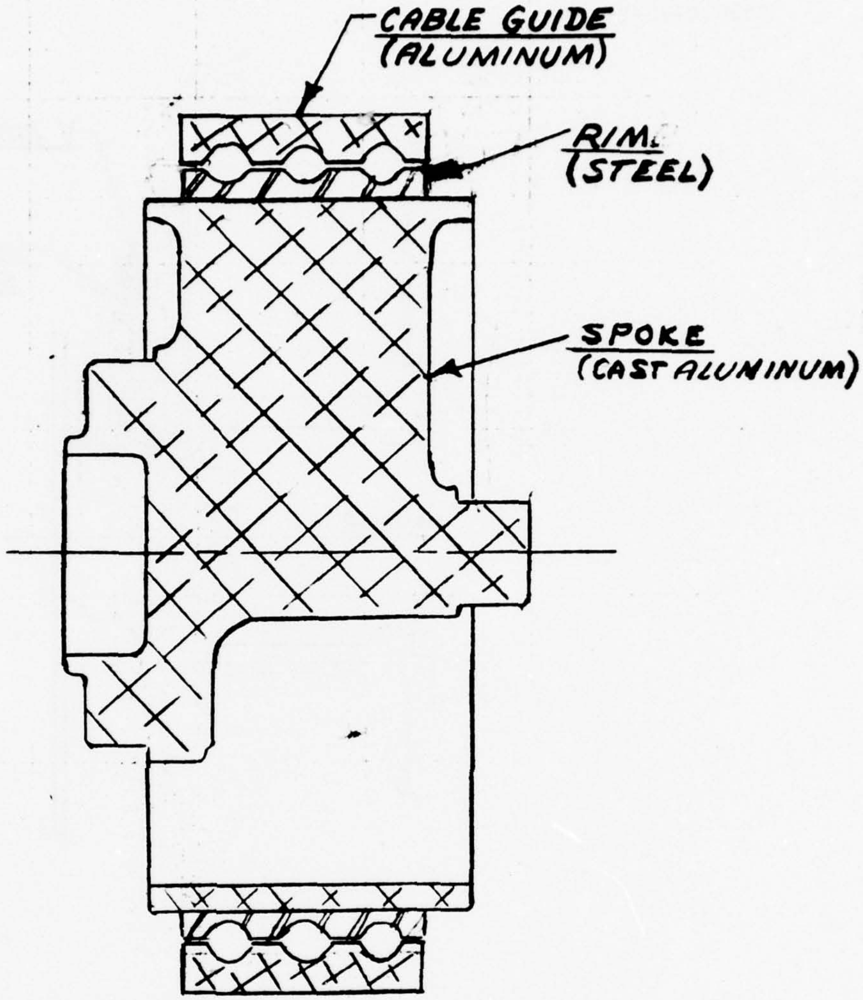
1. Traction Sheave Assembly
2. Boom Cover
3. Winch Cable
4. Guillotine Assembly and Support
5. Guide Tube
6. Sheave Motor Cable
7. Boom
8. Turnbuckle
9. Roof Stud
10. Adapter
11. Support
12. Locknut
13. Post
14. Boom Retaining Pin
15. Winch Power Cable
16. Control Box
17. Boom Actuator Electrical Cable
18. Pin
19. Floor Stud
20. Rubber Pressure Roller
21. Floor
22. Adapter
23. Actuator Lever
24. Winch
25. Hoist Motor Electrical Cable
26. Control Pendant
27. Hook Assembly
28. Pulley
29. Limit Switch
30. Trigger Assembly
31. Side Plate
32. Jam Nut
33. Adjusting Bolt
34. Guide Bolt
35. Actuator Lever Bolt
36. Actuator
37. Cup
38. Guillotine Switch

FIGURE 1



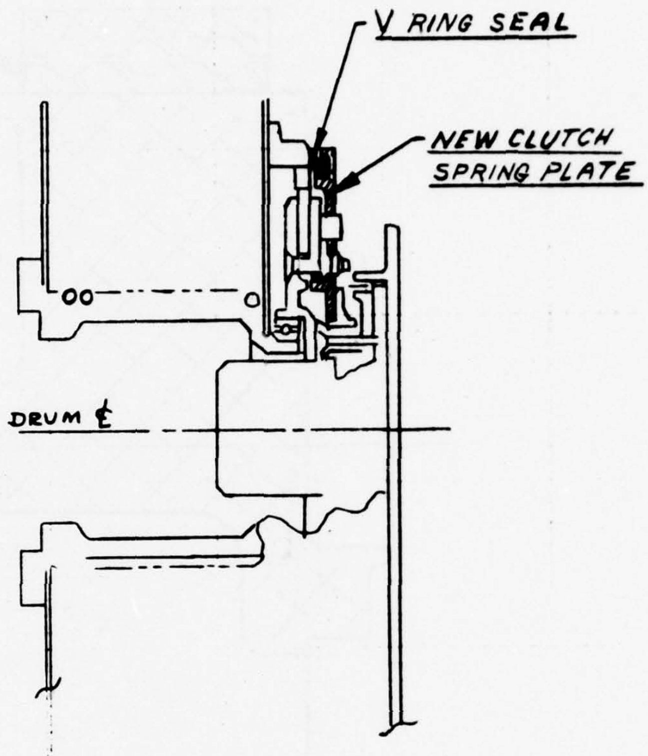
UPPER WINCH MOUNT

FIGURE 2



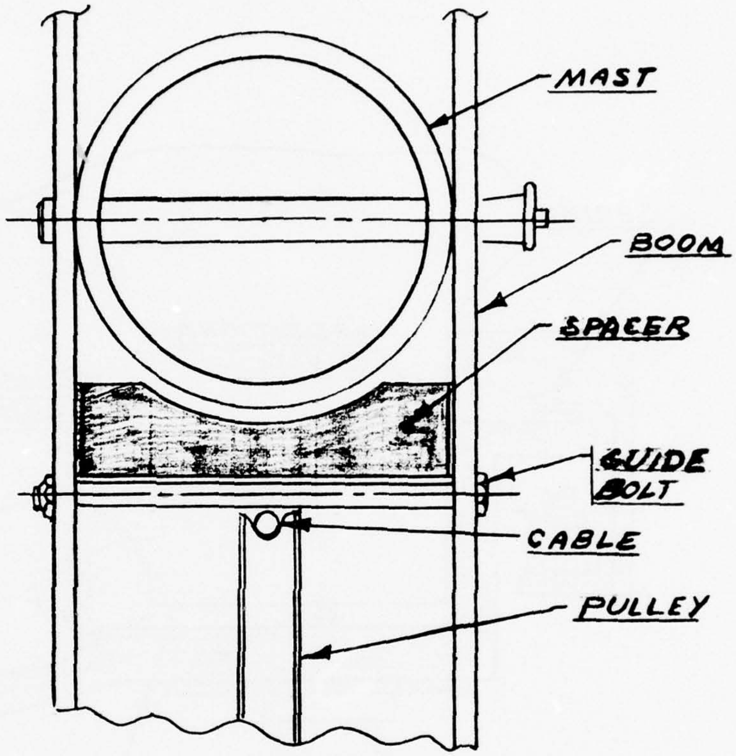
SECONDARY CAPSTAN (SECTION)

FIGURE 3



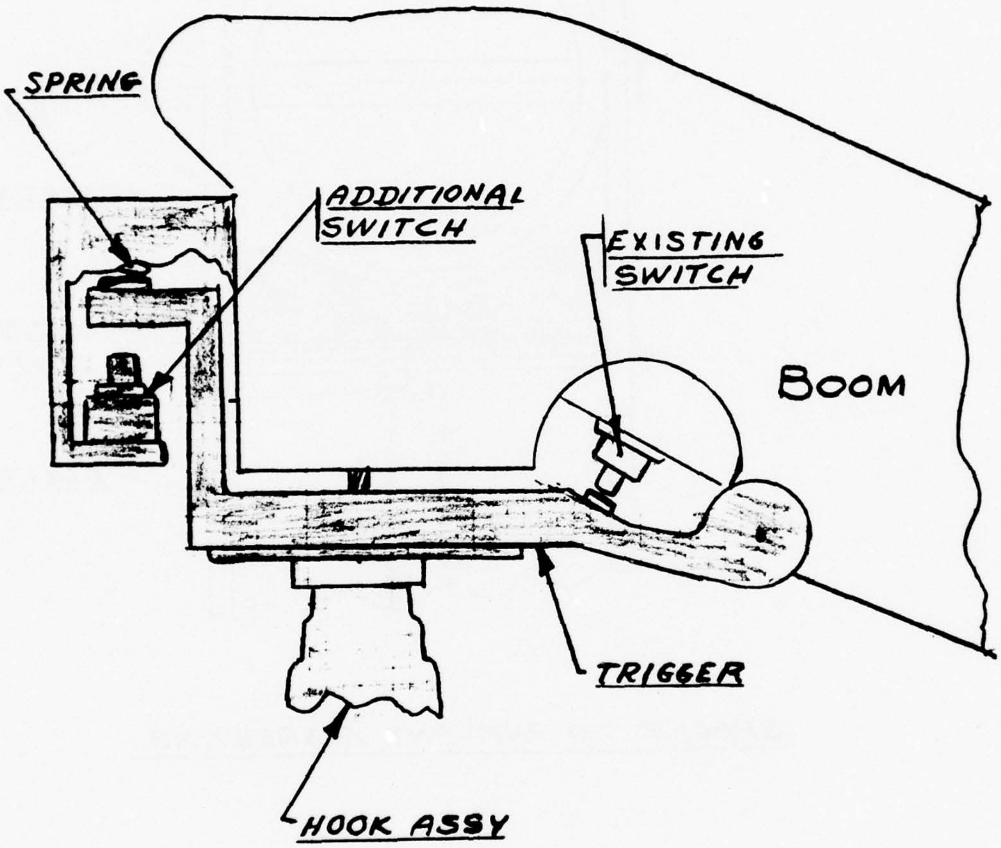
STORAGE DRUM CLUTCH SEAL (SECTION)

FIGURE 4



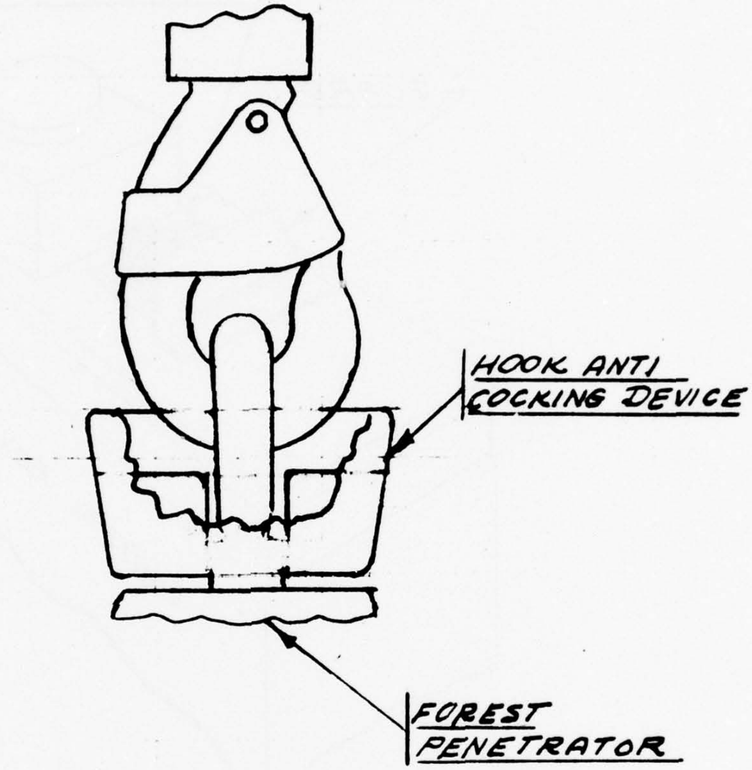
SPACER TO PREVENT MISREEVING

FIGURE 5



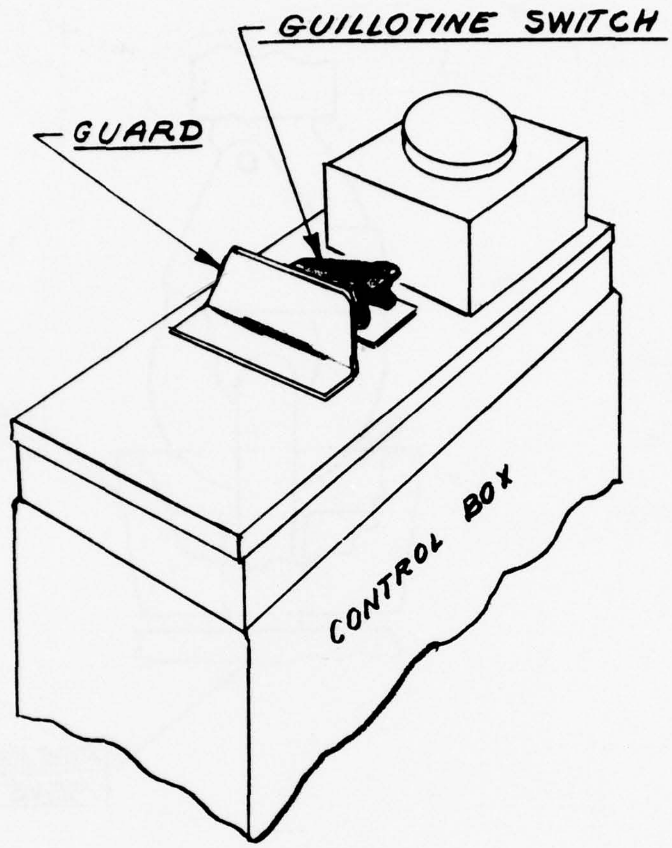
UP LIMIT SWITCH

FIGURE 6



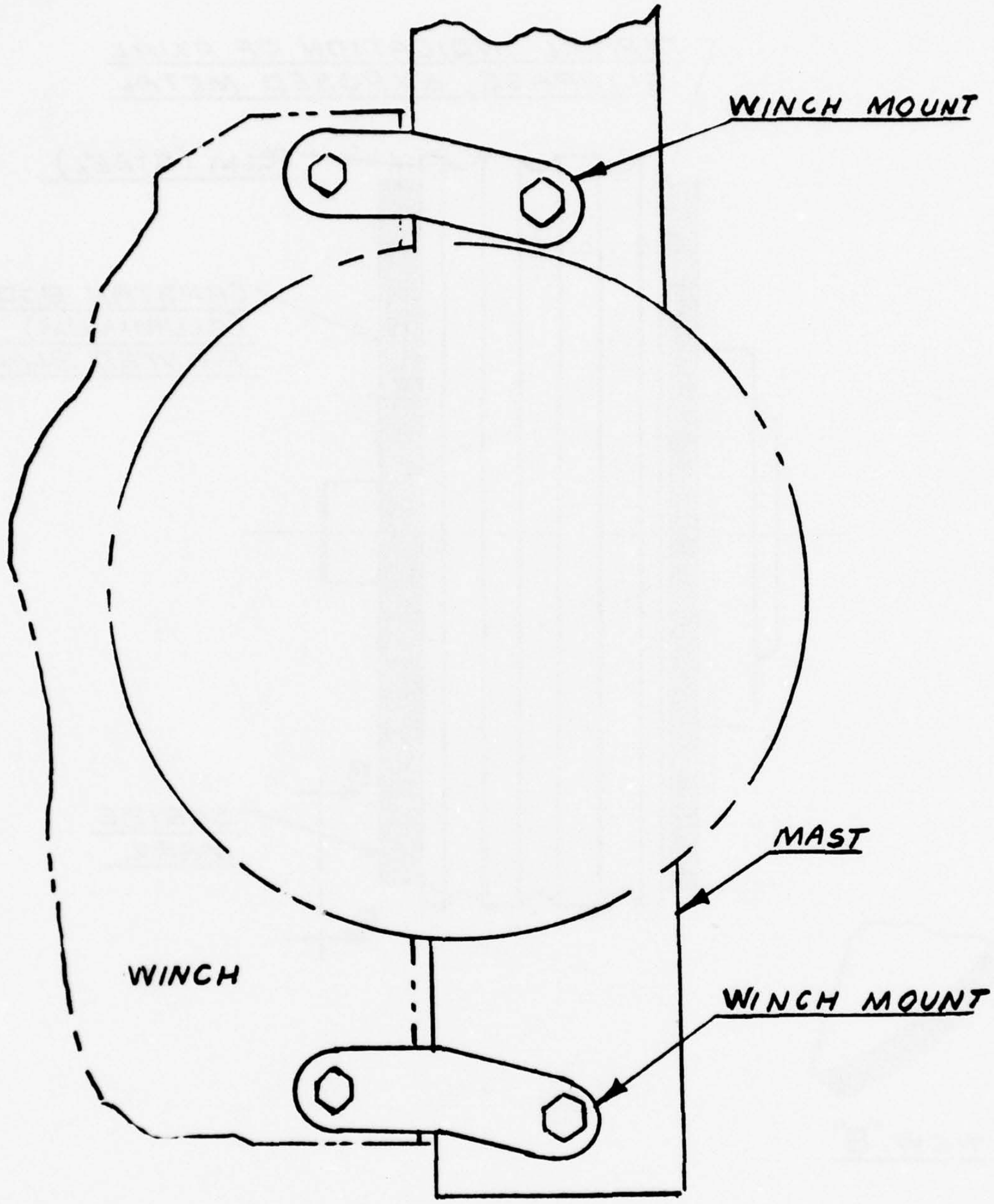
ANTI COCKING DEVICE

FIGURE 7



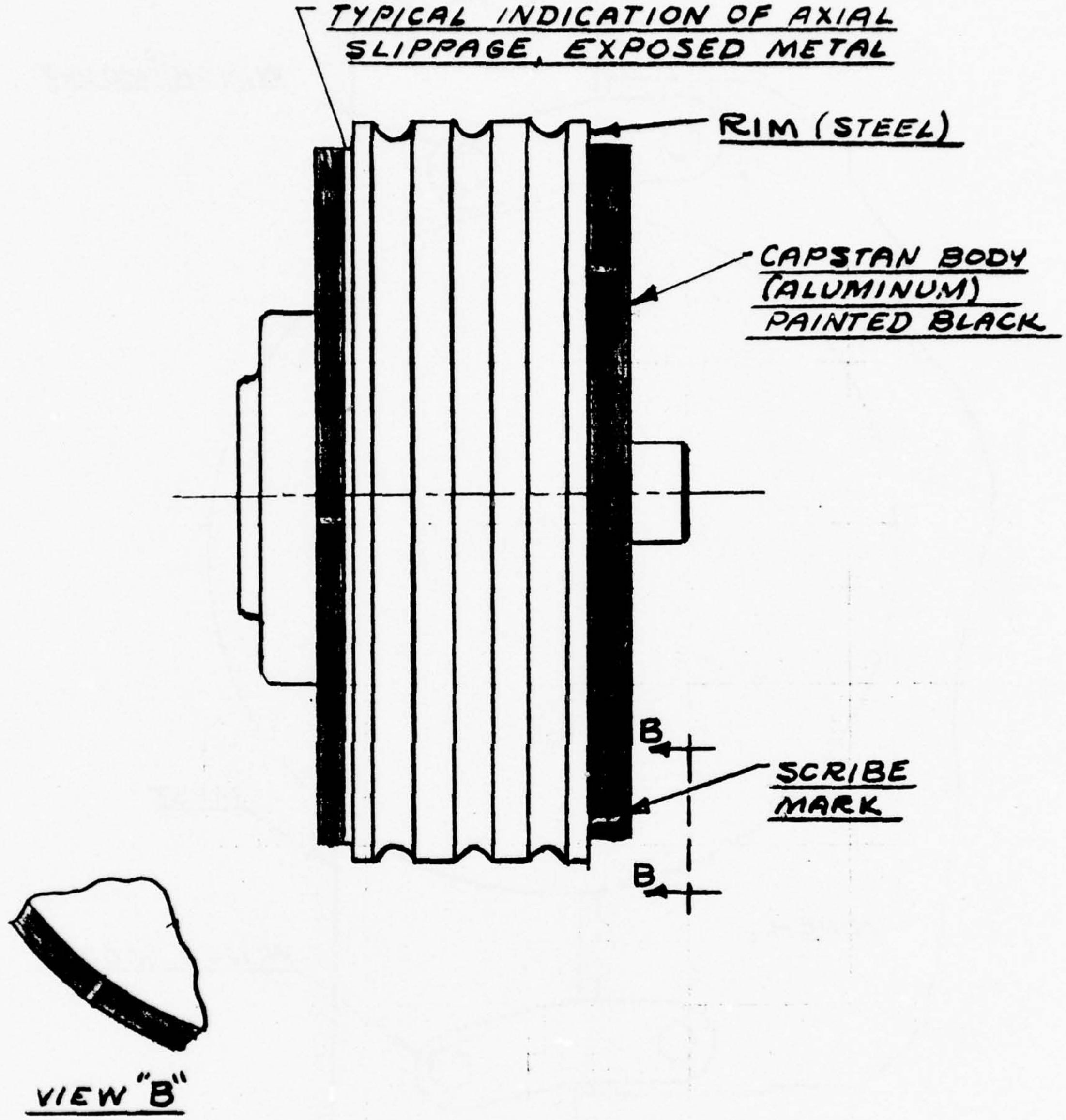
GUILLOTINE SWITCH GUARD

FIGURE 8



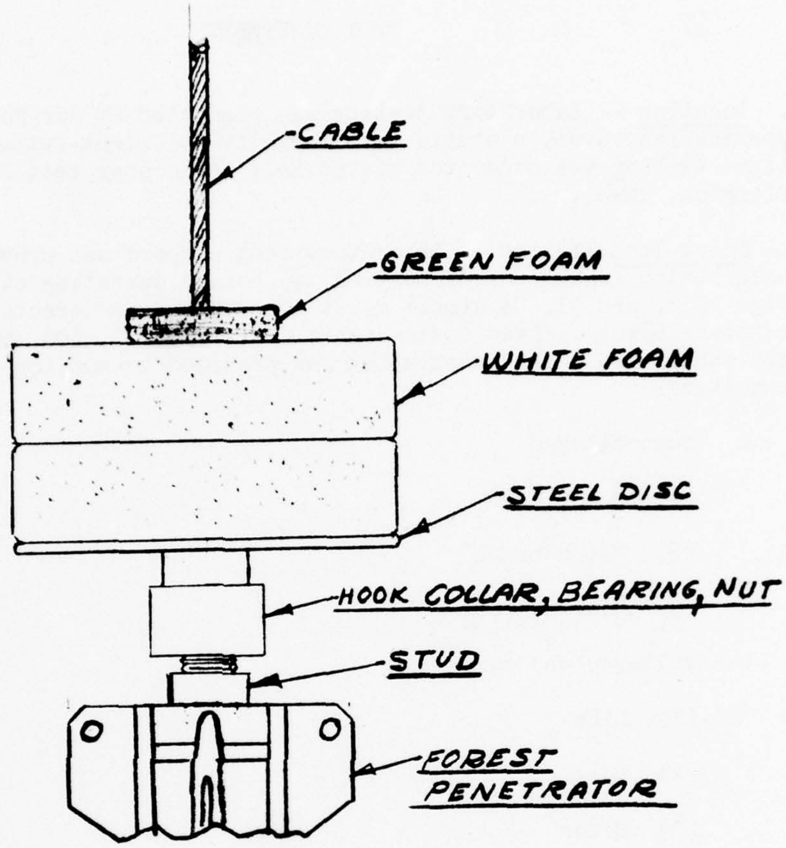
EXISTING WINCH MOUNT CONFIGURATION

FIGURE 9



SECONDARY CAPSTAN

FIGURE 10



SHOCK ABSORBER AND STUD

FIGURE 11

APPENDIX I

TEST EQUIPMENT

1. Location - Laboratory testing was conducted at Air Force Flight Dynamics Laboratory's static test facility at Wright-Patterson AFB, Ohio. Flight testing was conducted at the Bell Helicopter test facility, Arlington, Texas.

2. Hoist Installation - Laboratory test support was provided by a test installation capable of supporting two hoists operating simultaneously (Figs 1, 2, and 3). A simple maintenance stand was erected to assemble and store hoists. Lead test weights (25, 200, 262, 400, 600, and 3000 lb) were fabricated. Instrumentation was provided to monitor the following parameters:

a. Temperatures

(1) Motor case

(2) Motor brush

(3) Gear box oil

b. Voltages and currents

(1) Line

(2) Hoist

(3) Motor

(4) Control box

(5) Actuator

c. Load acceleration (accelerometer attached to 25 lb test weight)

d. Boom turnbuckle strut strain (strain gauge)

e. Cable speed (light photocell and mirror device)

f. Up limit switch activation

g. Cable tension (Fig 4)

3. Cable Fatigue - A cable fatigue test machine was built (Fig 5). This device somewhat simulates the actual hoist using pulleys. Two cables are tested simultaneously.

4. Cable Strength - Several ultimate cable strength test methods were utilized. Test method 1 (Fig 6) involved simple straight tension using a common tensile test machine. Test method 2 (Fig 6) involved duplicating the operational cable environment more closely. The cable was placed over a pulley (equivalent in size to the outer boom pulley) and allowed to rotate using a swivel. The third test method (Fig 7) attempted to simulate the operational cable environment. A forklift truck slowly lowered the 3000 lb weight until cable failure. A flag was used to note cable rotation.

5. Swaging - A manually operated roll type swager was used to swage the ball type end fittings onto cable samples.

6. Vibration - A vibration test rig was assembled at the static test laboratory (Fig 8). This consisted of a shaker table, a hoist, a load cell/ turnbuckle cable tension device, and an accelerometer.

7. Flight Testing - A hoist was instrumented and installed in a helicopter (Fig 9 and App III).

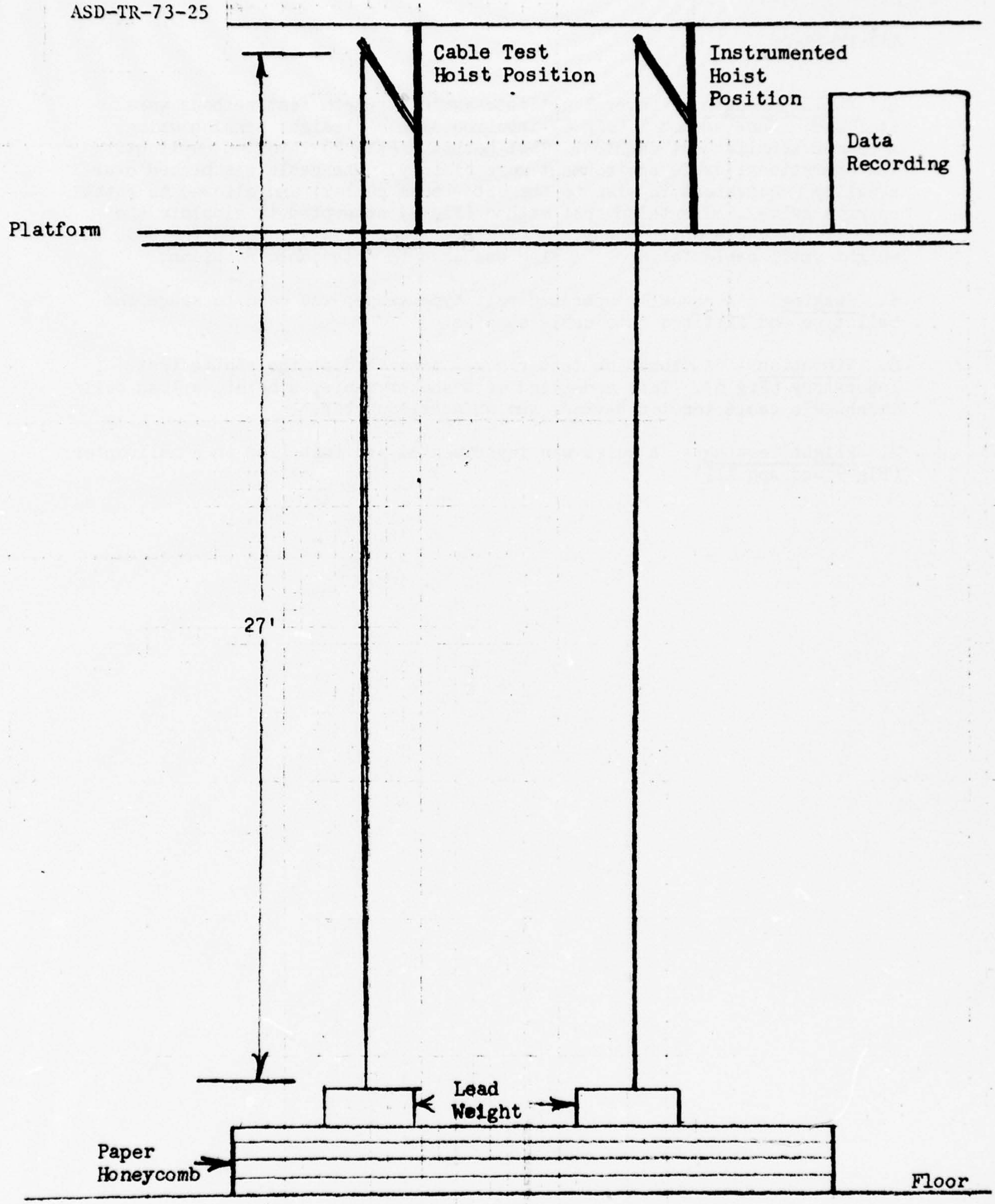


Figure 1 HOIST INSTALLATION

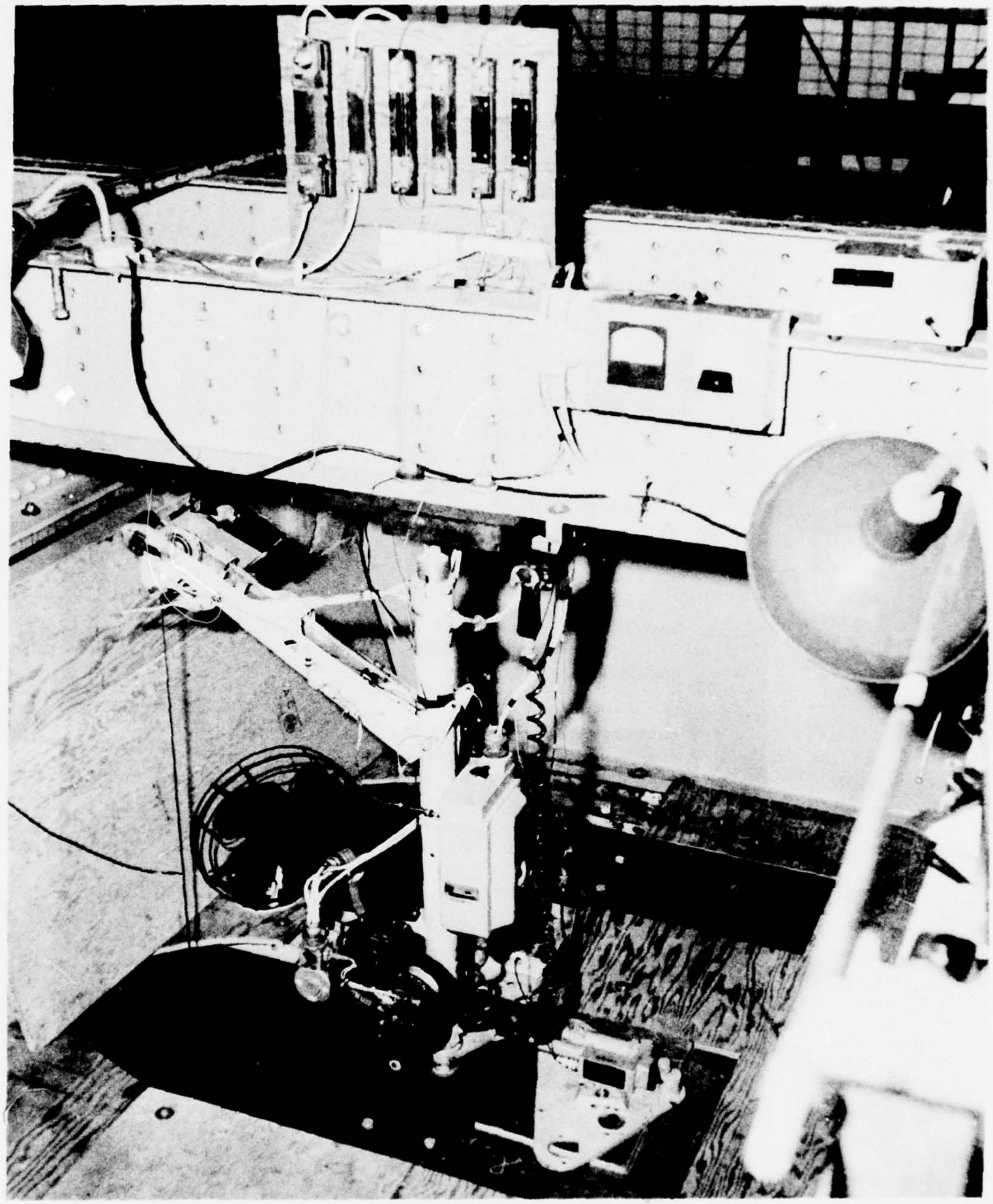


Figure 2 HOIST INSTRUMENTED
AND INSTALLED

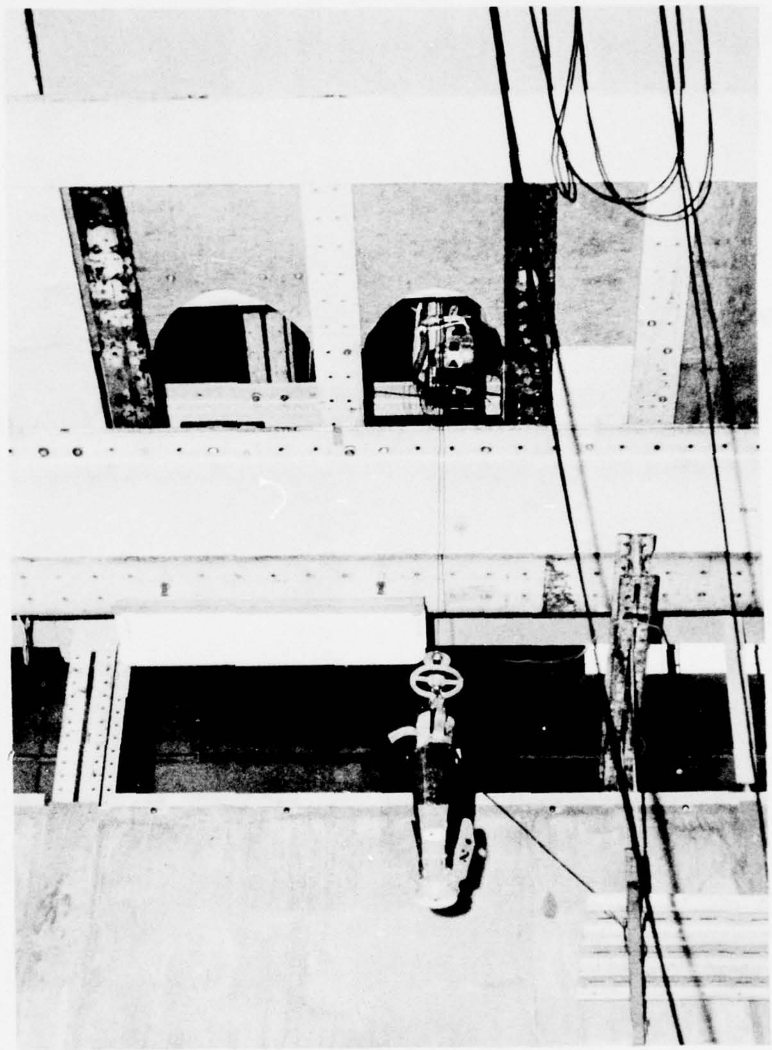


Figure 3 HOIST INSTALLATION
VIEW FROM FLOOR

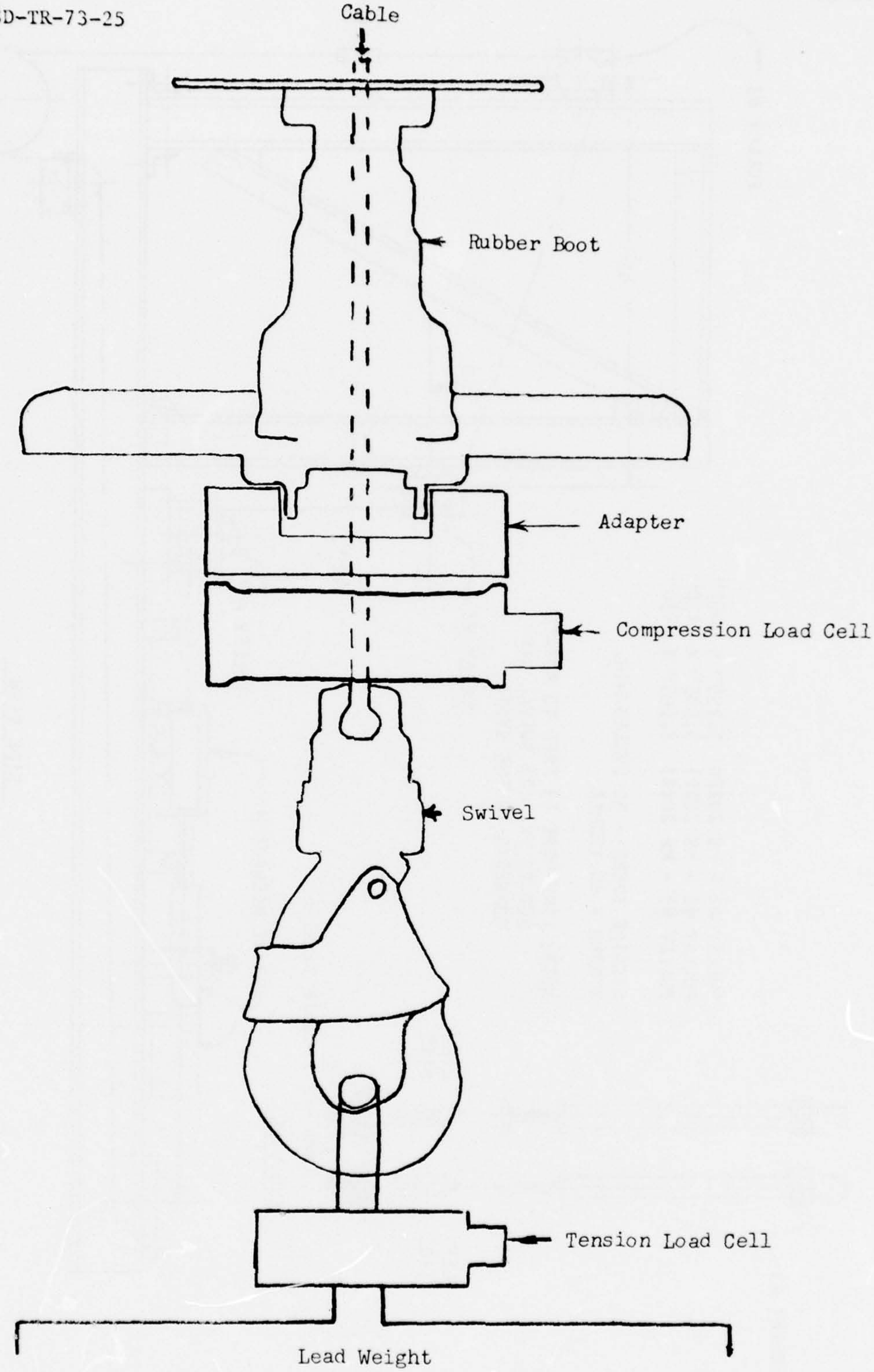


Figure 4 CABLE TENSION INSTRUMENTATION

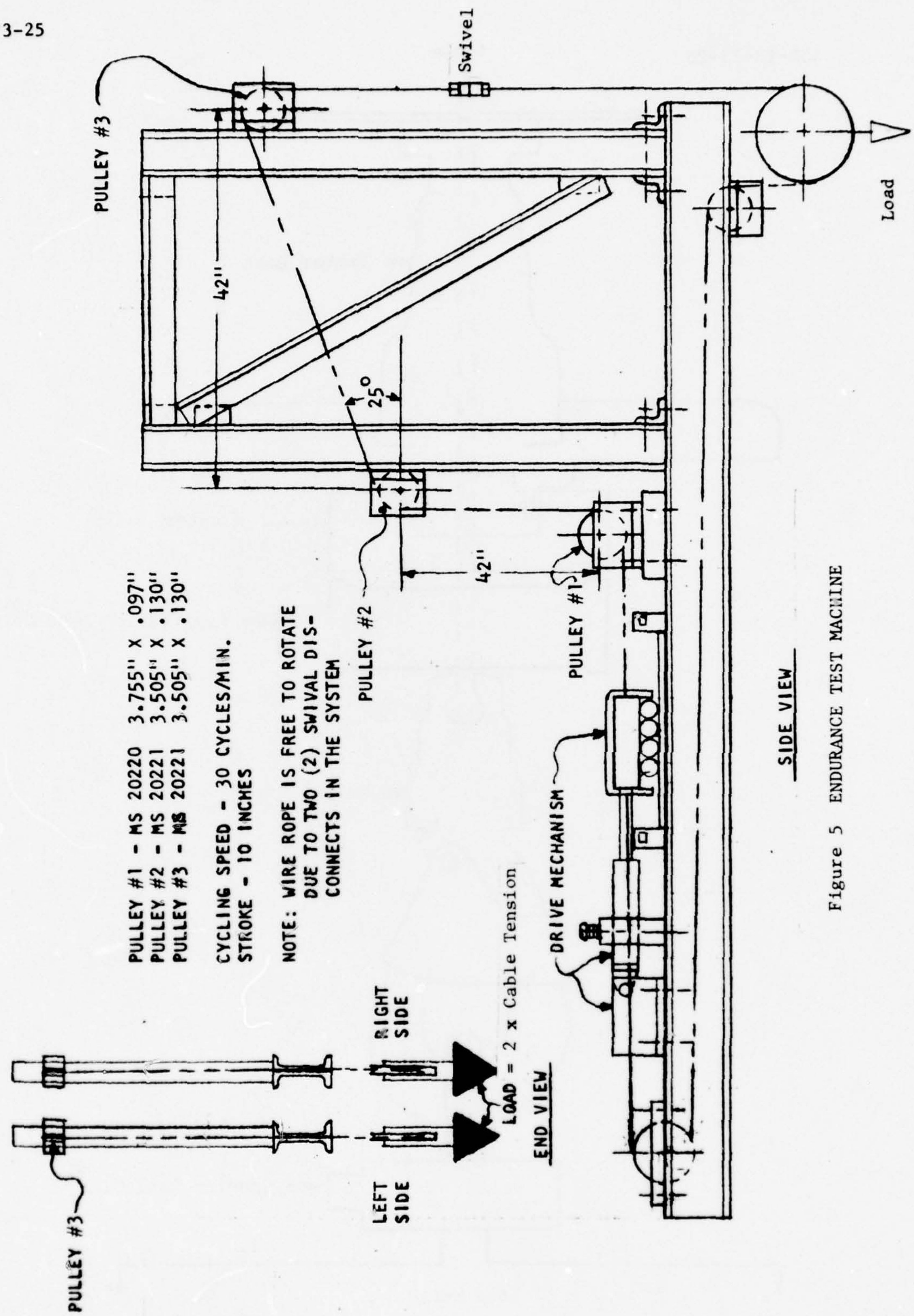


Figure 5 ENDURANCE TEST MACHINE

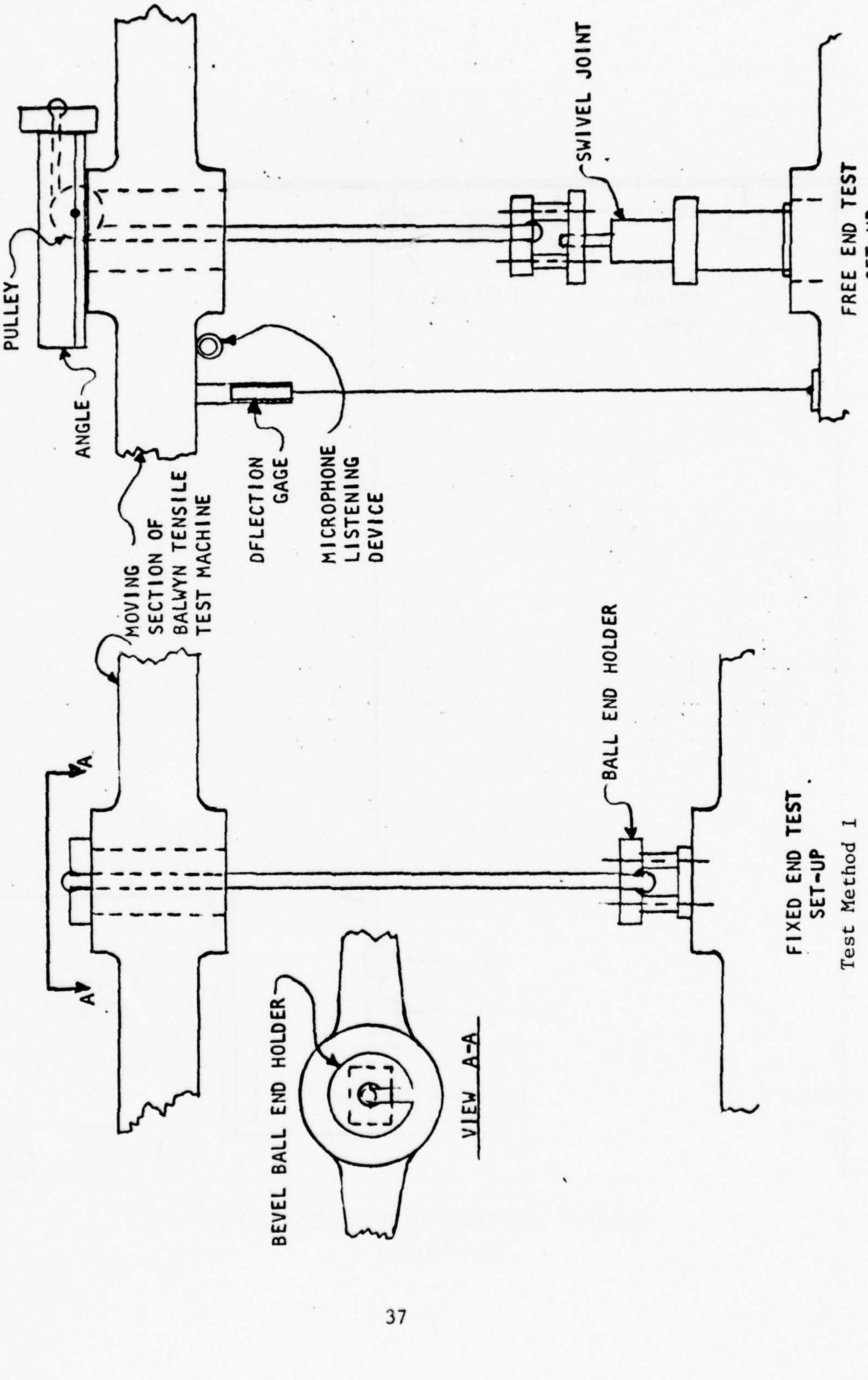


Figure 6 TENSILE TEST CONFIGURATION

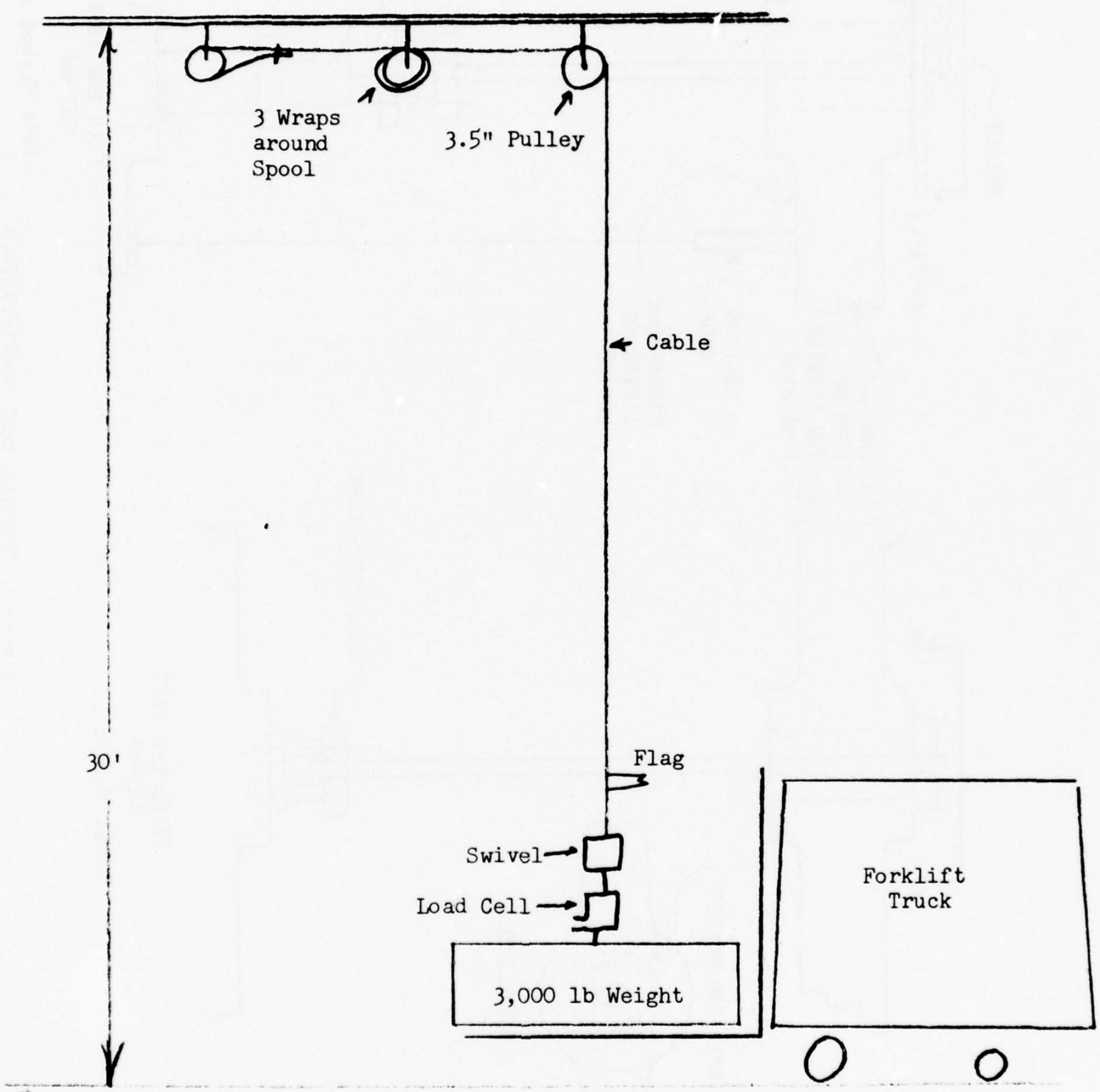


Figure 7 ULTIMATE CABLE STRENGTH TEST
Test Method 3

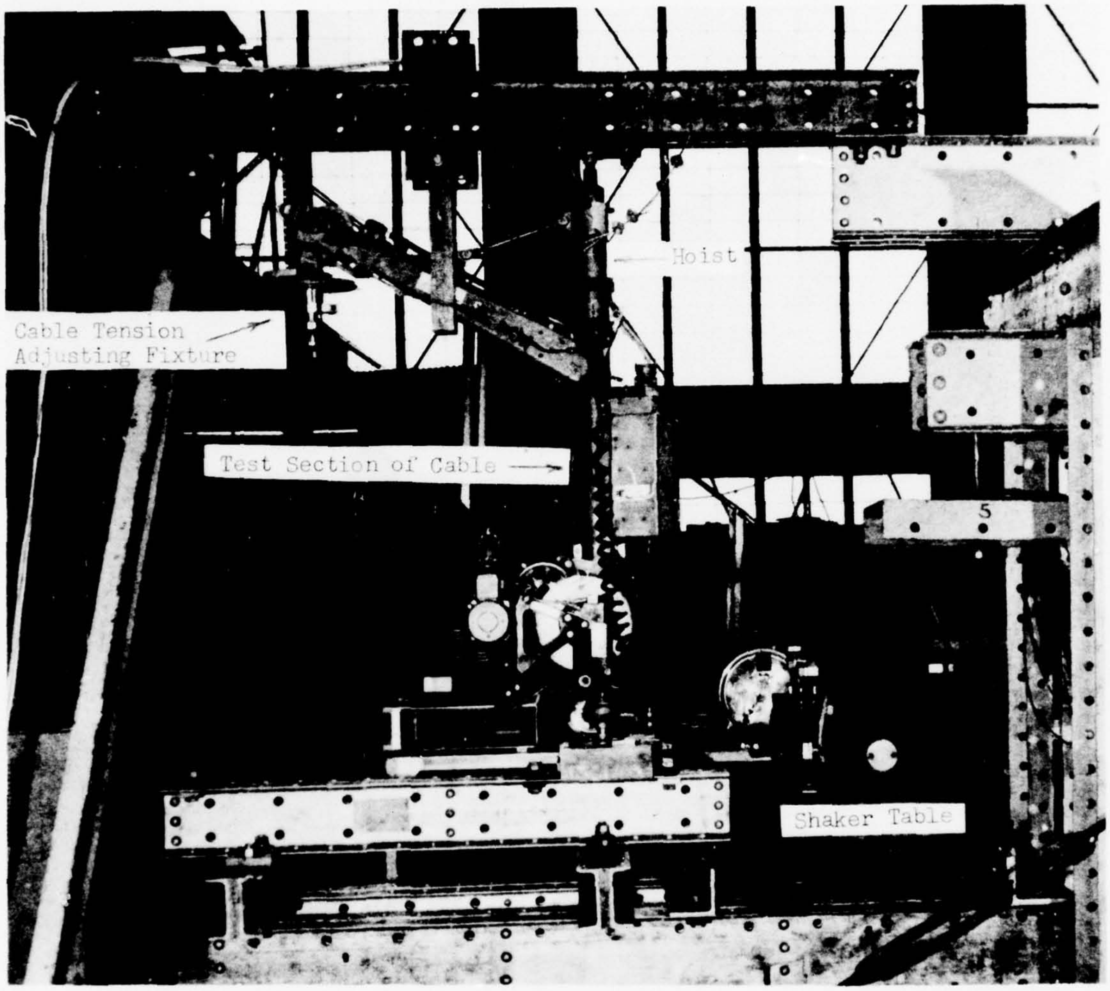


Figure 8 VIBRATION TEST

Figure 9 FLIGHT TEST INSTALLATION

APPENDIX II

INTERIM CLEARANCE

1. Background - MAC headquarters was extremely concerned over the loss of rescue training due to the UH-1N hoist restrictions. They requested that ASD determine if a limited, interim clearance could be granted. Clearance for the Homestead AFB survival school was considered a possibility because, in their operation, the student is lifted 10 feet above the water and then lowered. If the hoist failed, the student would fall back into the water with minimum injury potential. The CDR team was requested to perform such test and analysis as was necessary to define, and determine confidence in, a limited training clearance. The areas investigated were divided into two sections as follows:

a. Cable Wear and Fatigue - It was predetermined that the interim clearance would be based on starting with new MIL-W-83140 cable and replacing this cable at relatively short intervals. To support this position, a series of tests was accomplished to establish that the MIL-W-83140 cable could satisfactorily perform through a limited number of cycles. In addition, a determination was to be made to assure that MIL-W-83140 cable is at least equivalent to cable that had previously been supplied to a vendor specification (Breeze Corp Specification BMC-283-50).

b. Failure Mode and Effect Analysis - This limited analysis was pointed toward determining if there were known failure modes, with associated effects, that could be circumvented by simple mechanical means or procedural changes.

2. Test Procedure - The following test procedure was established in an effort to attain the objectives described above:

a. To simulate the rescue training operation at Homestead AFB, a 400-pound weight (student plus water with some safety factor) was attached to the hoist and subjected to multiple cycles. Each cycle consisted of the following:

(1) Induction of approximately five feet of slack cable, at the hook end, into a drum of salt water.

(2) Retrieval and induction of approximately four feet of slack cable, outside the drum, five times.

(3) Lifting the test weight 10 feet above the floor and lowering to the floor.

b. After each ten cycles the forest penetrator was attached and elevated to the position that it is normally swung into the aircraft.

c. After each 25 cycles, 50 feet of cable, plus the hook, was immersed in tap water and agitated (as in washing) with subsequent drying.

d. The above procedure was essentially followed through the first eight multiple cycle tests. The water immersion was eliminated after 1,600 cycles because it required too much time for the accelerated interim testing. Test number 9 was a single pull (no previous cycling) tensile test of new cable. Tests 10 through 13 were single pull tensile tests of used cable with a known number of field operating cycles (not test cycles). Prior to each cycling test, base line specimens were taken from the end of each sample and pulled to failure. After each cycling test, specimens were taken from potential high stress locations and pulled to failure. Pre-cycling and post-cycling strengths were compared. The following is an outline listing of the cable testing.

Test No	No of Test Cycles	No of Field Cycles	Cable Sample Numbers
1	800		1A
2	800		2A
3	50		2B
4	100		3A
5	200		3B
6	400		4A
7	800		4B
8	800		3B
9	0		5A
10		503	6A
11		1939	7A
12		503	6B
13		1939	7B

(1) Pre-Cycling Specimens - Three pre-cycling test specimens were taken from each cable sample that was to be subjected to test cycling (tests 1 through 8) and pulled to failure, using a test method where the ends are not free to rotate (Fig 6, App I, Test Method 1).

(2) Post Cycling Specimens - Two methods were used to pull test post cycling specimens. In the first case, three-foot specimens were cut

from seven hoist locations. These locations were measured with the test weight resting on the floor. The specimens were then pulled to failure in a tensile test machine with the ends fixed. This procedure is shown in Fig 6, App I, and was designated Test Method 1 test. The hoist locations are as follows:

Hook end

Traction sheave

Inboard boom pulley

Primary capstan

Secondary capstan

Level wind idler pulley

Storage drum

In the second post-cycling test case, a long section of cable was cut, which encompassed all the above hoist locations, and pulled to failure with the loaded end free to rotate (Fig 7, App I). This test procedure was designated Method 3 test.

(3) Cable Identification - Tests 1 through 9 were conducted with new cable in accordance with MIL-W-83140. This cable is referred to as Type A cable. Tests 10 through 13 were conducted with cable in accordance with a vendor specification (Breeze Corp Specification BMC-283-50), which had been returned from the field after a known number of operating cycles. This cable is referred to as Type B cable.

(4) Sample Identification - Individual test samples of cable were referred to as 1A, 1B, 2A, 2B, etc. As an example, in test no 1, 800 cycles were put on a section from a given length of cable, and this was identified as sample 1A. In test no 8, a second section was taken from the remainder of the cable length and designated as Sample 1B.

3. Cable Test Results - Results of cable testing are graphically depicted in Figures 1 and 2. Of note is the lack of degradation in cycled cables and the difference in cable strength when the ends are fixed (Method 1) and when an end is free to rotate (Method 3).

4. Hoist Mechanical Investigation - Early in the CDR a complete hoist assembly was received from Homestead AFB. The hoist appeared to be extensively used, but exact usage was unknown. The hoist was inspected, filled with oil, the up-limit switch adjusted, and a new MIL-W-83140 cable was installed. Testing was started and proceeded as shown in paragraph 2.d of this section. In addition, cable tension data was recorded with various weights and dynamic conditions (Table 2). During the cable testing, several mechanical problems were encountered with the hoist. These events are described and rationalized as follows:

a. Pendant Control - The rubber boot that protects and centers the winch control switch split open after 264 cycles. The boot gradually degraded until, at the completion of cable test no 1, it was completely inoperative. Impending failure of the boot is readily apparent and a new boot can easily be installed. Subsequent CDR testing showed that a new boot will last at least 3,000 cycles.

b. Up-Limit Switch - A gross misadjustment of the up-limit switch actuator screw was observed at cycle 782. Vibration had apparently caused the screw to back out. The switch was readjusted and the problem did not recur. This failure was considered the most significant that occurred during interim testing. At this time, a foam shock absorber was designed for installation between the hook assembly and boom. Testing showed that this foam shock absorber would reduce the cable tension load, caused by an inoperative up-limit switch, from 3,000 to 1,600 pounds. It was also learned that a shock absorber could be utilized to indicate (by major deformation) that an inoperative up-limit switch condition had been encountered.

c. Oil Leakage and Clutch Contamination - Originally, the intent had been to limit gear box oil temperature below 200°F. This temperature limit so grossly slowed the interim cable test that the limit was raised to 230°F. At this temperature gear case oil was bubbling out of the vent and seeping through seals. After 416 cycles of Test no 1, about one ounce of oil had been lost. It is emphasized that oil leakage was primarily caused by excessive temperature. The storage drum clutch started slipping at 474 cycles. Twelve cycles later the winch was replaced with an overhauled unit. Cause of the malfunction was oil contamination in the clutch. Origin of the oil was undetermined. Subsequent testing with associated oil leakage failed to cause a clutch malfunction. Figure 3 depicts the gear box oil temperature rise plotted against continuous cycles. It should be noted that excessive temperature was reached only after 32 continuous cycles.

d. Secondary Capstan - The winch started making a clicking noise after 776 cycles into test no 2. The noise occurred every capstan revolution when lifting the load and appeared to be coming from the secondary capstan area. No associated abnormalities could be discovered during the remainder of the test.

e. Down-Limit Switch - The down (extended cable) limit switch on the storage drum failed at the completion of test no 2. This failure would not allow cable to reel out. An examination revealed a broken wire in a connector which caused the open circuit failure. The entire down-limit switch circuit was purposely shorted out so that the cable test could be continued.

5. <u>Conclusions and Recommendations</u> - Previous operational failures, test malfunctions, and cable load data from static and flight test were analyzed. The applicable flight load data was obtained from the Bell Helicopter Company test and is summarized in Table 1. It was concluded that a malfunctioning or misadjusted up limit switch created the highest potential for immediate cable failure without prior warning. It was also concluded that interim use of a shock absorber would drastically reduce the failure potential and could be designed to give permanent indication of an initial up limit switch failure. From the cable testing it was shown that MIL-W-83140 cable could be expected to perform at least 500 normal operating cycles without appreciable strength degradation. Based on the above, an interim clearance was recommended. On 22 November 1972, Homestead AFB resumed training operations with shock absorbers and new MIL-W-83140 cable.

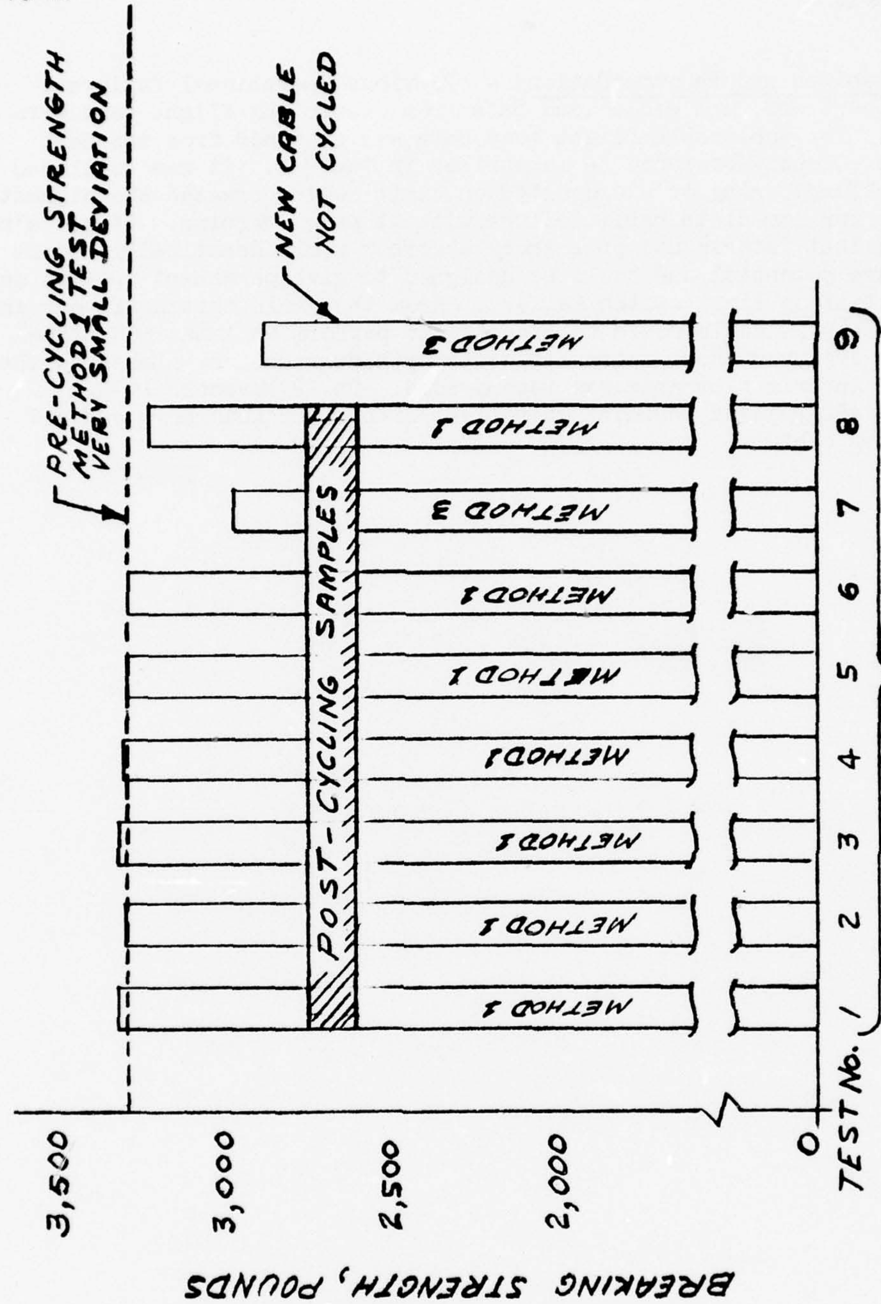


FIGURE 1 INTERIM CABLE TEST

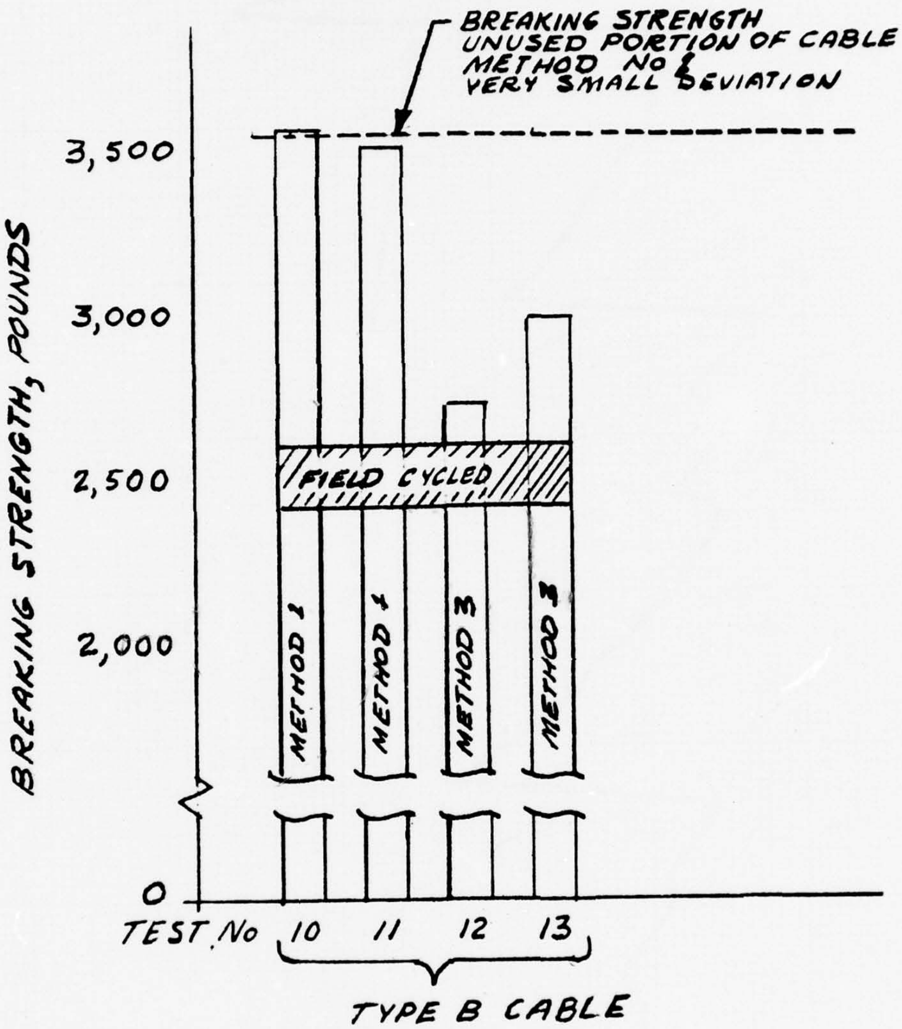


FIGURE 2
INTERIM CABLE TEST

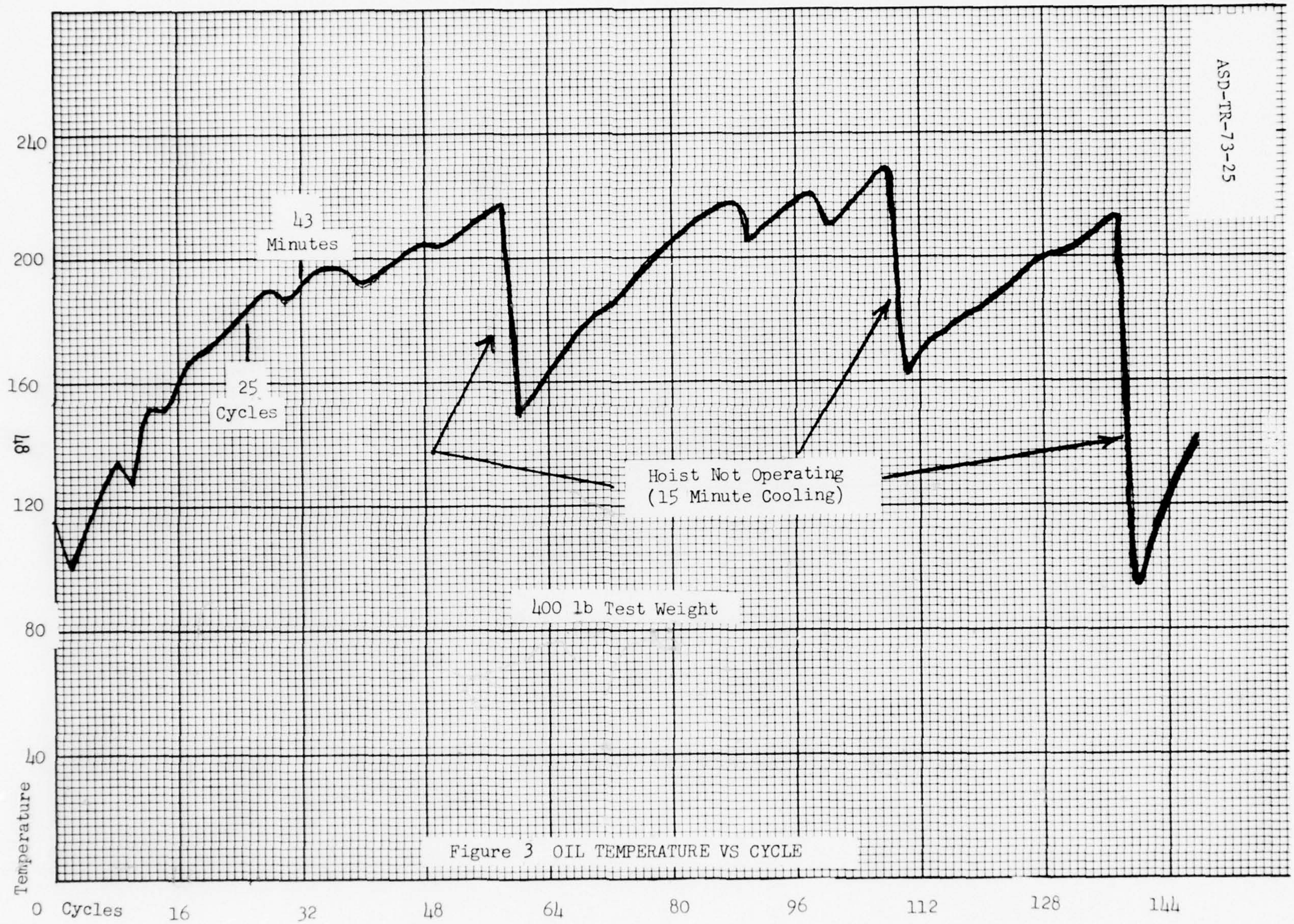


Figure 3 OIL TEMPERATURE VS CYCLE

	CABLE TENSION AT VARIOUS WEIGHTS			
	25 lb	225 lb	400 lb	600 lb
Cable Travel: 'Down' (Normal Mission)	72	336/450*	600	1014
Cable Travel: 'Up' (Normal Mission)	90	450	840	1270
Impact With Operative Up Limit Switch: (0.01" gap) (Normal Mission)	365	621	923	1076
Impact With Operative Up Limit Switch: (0.25" gap)	772	458		
Impact With Inoperative Up Limit Switch	3028	3005	3095*	2825
Jogging Operation		810	920	1278
Collective Bounce (Simulated Rough Weather)			822	

*Weight was saturated with water.

Table 1 FLIGHT TEST CABLE TENSION DATA

	CABLE TENSION AT VARIOUS WEIGHTS			
CONDITION	25 lb	225 lb	400 lb	600 lb
Cable Travel: 'Down' (Normal Mission)	50	475	575	875
Cable Travel: 'Up' (Normal Mission)	40	375	625	900
Impact With Operative Up Limit Switch (0.10" gap) (Normal Mission)	500	500	475	450
Impact With Inoperative Up Limit Switch	2500	2500	2400	2350
Jogging Operation	75	700	1175	1600
Impact With Inoperative Up Limit Switch and with Plastic Foam Shock Absorber	1600			

Table 2 STATIC TEST CABLE TENSION DATA

APPENDIX III

TEST REPORT FOR UH-1N HOIST

GROUND AND FLIGHT TEST

Engineering Services Contract

F09603-73-C-0007

Task No. 3

SUMMARY AND RECOMMENDATIONS

The Flight Test Program for the UH-1N Hoist was conducted at Bell Helicopter Flight Test Facilities between 23 October and 3 November 1972. The program test points were adjusted as shown to provide more adequate data.

Table I indicates that for conditions where the micro-switch is inoperative, cable loads exceeding 3000 pounds can be obtained. When the control switch is operated to intentionally beep (jerk) a load, forces to approximately 3 g's can be generated, in the case of the 225-pound load. Start up "g" forces can be considerable even when not intentional, as can be seen in the force of 621 pounds for a 225-pound load, and 90-pound force for a 25-pound load. As might be expected, the trend is for lower "g's" as the load weight increases. The collective bounce produced slightly over 2 "g's" but the roughness of the ride exceeded that for rough air handling.

The hoist cable was furnished, per request, to ASD for analysis.

The following list of recommendations are considered appropriate to this data:

1. Up and down travel deceleration provisions will help to reduce loadings.

2. Limit switch redundancy should be improved by dual switching to minimize switch failure loadings.

BACKGROUND

Several UH-1N rescue hoist/cable failures during the past year have prompted the USAF to restrict "live" pickups to actual emergencies only while ASD conducts a critical design review of the system. This design review is intended to assure all potential problems are identified and corrected or ascertain that the hoist cannot be cost effectively modified to perform the mission(s) assigned. A complete resumé of previous hoist experience, together with itemized factors to be considered during the design review, can be found in the "minutes of the UH-1 rescue hoist meeting 24-25 August 1972", dated 7 September 1972.

OBJECTIVE

(1) Determine the effects of varying loads on the hoist during flight tests at BHC.

(2) Prepare a general test report in accordance with DI-T-3718/T-119-Z/M including an outline of any recommended follow-on test effort (4 copies).

STATEMENT OF WORK

Phase II -

(1) Install GFP UH-1N rescue hoist on bailed UH-1N helicopter.

(2) Instrument to the extent the following parameters can be monitored:

A. Cable tension load

B. Hoist boom load

C. Electric power to winch

D. Boom actuator load

E. Electric power to traction sheave

F. Cable movement through upper boom using hi-speed camera

(3) Flight test as follows at a skid height of approximately 15 feet using dummy loads:

A. Over land and water

B. In rough and smooth air

(4) While accomplishing (3) A and B vary hook loading and limit switch settings as follows:

Lbs Hook Loading	Load Varying Limit Switch Setting
25	0.10", -4", inoperative
225	0.10", -4", inoperative

(5) Upon completion of testing accomplish a teardown inspection of hoist cable.

REPORTING

(1) BHC is to report interim findings at least every 30 days by status letter in accordance with Engineering Doc. 80-1. A copy of each report is to be furnished to Logistics Contracts.

(2) A final General Test Report in accordance with DI-T-3718/T-119-Z/M and 80-1 is required 60 days after completion of flight evaluation. In addition, an outline of suggested follow-on testing recommendations shall be submitted with the final report.

FLIGHT TEST PLAN

I. Instrumentation:

Instrument GFP UH-1N rescue hoist for monitoring the following parameters during test.

A. Cable Tension Load - Installation of load cell between hook and end of cable. HES required to machine special fitting per instrumentation definition.

B. Hoist Boom Load - Installation of instrumentation on 205-072-234-1 turnbuckle in order to record both tension and compression loads.

C. Electric Power Load to Winch - Installation of instrumentation to record electrical load experienced by the power winch.

D. Boom Actuator Load - Installation of instrumentation to record both electrical and mechanical loads experienced by the boom actuator during operation.

E. Electric Power to Traction Sheave - Installation of instrumentation to record electrical loads experienced by the traction sheave during operations.

F. Cable Movements through the Upper Boom Section - Installation of a high speed camera to record cable movements during test operations.

II. Test Plan:

Flight test to conduct hoist test, using two Air Force hoist operators to operate hoist throughout the entire testing program. Each Air Force hoist operator will operate the hoist through the complete set of test operations outlined below and will operate the hoist only. They will not have any control of the instrumentation or aircraft operation. Tests to be conducted are as follows:

* A. All flight tests to be conducted at a skid height of approximately 15-20 feet from ground/water level.

B. All hoist operations are to be at full speed and full stroke.

III. Ground Level Test:

Test Number One
Lbs Hook Loading = 25 Limit Switch Setting = 0.10"

Test Number Two
Lbs Hook Loading = 225 Limit Switch Setting = 0.10"

*Test Number Three
Lbs Hook Loading = 25 Limit Switch Setting = 0.4"

*Test Number Four
Lbs Hook Loading = 225 Limit Switch Setting = 0.4"

Test Number Five
Lbs Hook Loading = 25 Limit Switch Setting = Inoperative

Test Number Six
Lbs Hook Loading = 225 Limit Switch Setting = Inoperative

Each of the above tests are to be repeated such that both of the Air Force hoist operators have completed test numbers (1) through (6).

* IV. Water Level Test:

Test Number Seven
Lbs Hook Loading = 25 Limit Switch Setting = 0.10"

Test Number Eight
Lbs Hook Loading = 225 Limit Switch Setting = 0.10"

*Test Number Nine
Lbs Hook Loading = 25 Limit Switch Setting = 0.4"

*Test Number Ten
Lbs Hook Loading = 225 Limit Switch Setting = 0.4"

Test Number Eleven
Lbs Hook Loading = 25 Limit Switch Setting = Inoperative

Test Number Twelve
Lbs Hook Loading = 225 Limit Switch Setting = Inoperative

TEST RESULTS

General

A flight test was conducted on a Breeze Internal Rescue Hoist installed in a helicopter during 1 and 2 November 1972 at Arlington, Texas. The helicopter was a bailed Air Force UH-1N, BHC S/N 31001. The hoist was Government furnished equipment identified as "Unit 0005" and otherwise identified as follows:

NAME	BREEZE NO.	S/N
Hoist Assembly	BL-8300-32	233-C
Hoist Control Box	BL-81120-11	176-C
Pendant Control	BL-8430	1104-C
Traction Sheave	BL-13800-1	211-C

The hoist was installed in the forward left hand position. Instrumentation and testing were as listed with some additional test points and weights as requested by Messrs P. Eodice and D. Day of ASD.

Results

Table I, presents the highest loads recorded for the four weights in the seven listed conditions. Note that all weights were not tested in all conditions.

Table II is a listing of all lifts made and the data presented are peak values recorded during each counter, and in no way reflect steady state conditions. A description of Table II columns is as follows:

Weight - Denotes weight of object listed and direction of weight travel. "In" and "Out" denotes boom swing into and out of helicopter.

Microswitch Position - Dimension in inches of clearance between the micro-switch plunger and the actuating arm. "Inop" denotes an adjustment so large that micro-switch would not stop cable motion, and thus allowed winch to stall at full "up" position.

Maximum Upper Limit Load - This is the value measured by a compression member installed between the hook and the end of the boom, and measures the load that is generated by the winch pulling against a hook that has "bottomed out" against the boom. The value will always be "0" in the down direction, and is shown as "0" at other times because the value was too small to accurately read. The minus sign (-) indicates a compression load.

Maximum Load Link - An instrumented load link was inserted between the hook and the load being lifted. These values reflect g forces at the starting or stopping of cable movement.

Maximum Compression Load + Corresponding Tension Load - This is the sum of the absolute values of the Maximum Upper Limit Load column value and the load link value occurring at that point, which usually is not the maximum load link value. This load is the total cable tension seen by the winch.

Maximum Hoist Boom Load - This is the load recorded in the turnbuckle that supports the boom.

Hoist Winch/Boom Actuator/Traction Sheave - These reflect maximum in-rush current and the corresponding voltages. The boom actuator was instrumented only in the "in" leg of the wiring, therefore shows a value only during the swing in.

Counters 86 through 89 were repeated by Counters 122 and 123. Counters 97 through 104 were partially void due to the operator lowering the hook below the length limit of the instrumentation cable. These were repeated at Counters 112 through 116. An operation noted as "Jerky" indicates that the operator was pulsing the hoist control switch.

At Counter 150 the boom actuator control circuit failed so that the "in" control signal was continuous. The actuator was unplugged, the boom manually swung out and locked, and the test continued.

High speed motion pictures of cable movement at the end of the boom were partially obscured by shadows of the pulley sides. It could be seen that the cable did not tend to jump and did appear to track smoothly in the pulley. It could not be determined if the cable had a tendency to rotate.

* Notes:

Test plan was modified at the request of Mr P. Bodice of ASD and concurred in by BHC Engineering Project. These changes were made as tests progressed to obtain more meaningful data.

1. Limit switch settings changed to 0.1, 0.25 and inoperative. The inoperative point on micro switch was 0.35 inch.

2. Skid height used was same as operator used at Homestead AFB and Fairchild AFB.

3. 400- and 600-pound test loads were added in lieu of some over water test points.

4. Jerky operation and collective bounce were utilized to simulate rough air since atmospheric conditions were not available.

5. ASD requested and received the hoist cable after flight tests were accomplished.

CONDITION	25 LB.	225 LB.	400 LB.	600 LB.
CABLE DOWN TENSION	72	450 Water Saturated	601	1014
CABLE UP TENSION PRIOR TO IMPACT (NON JERKY)	90	621	840	1270
TOTAL CABLE TENSION AT IMPACT FOR .1 MICRO SWITCH SETTING	365	621	923	1076
TOTAL CABLE TENSION AT IMPACT FOR .25 MICRO SWITCH SETTING	772	458	----	----
TOTAL CABLE TENSION AT IMPACT FOR INOP. MICRO SWITCH SETTING	3028	3005	3095	2825
TOTAL CABLE LOAD FOR JERKING	----	810	920	1278
TOTAL CABLE LOAD FOR COLLECTIVE BOUNCE	----	----	882	----

TABLE I
Summary of Maximum Loads
Internal Rescue Hoist Test Data

TABLE II 1 of 9

Internal Rescue Hoist Test Data

CTR	WEIGHT	MICRO SWITCH POS.	MAX. UPPER LIMIT LOAD (Compression)	MAX. LOAD LINK (Tension)	MAX. COMPRESSION LOAD + CORRESPONDING TENSION LOAD	MAX. HOIST BOOM LOAD	HOIST WINCH MOTOR		BOOM ACTUATOR		TRACTION SHEAVE		COMMENTS
							MAX CURR	MAX VOLT	MAX CURR	MAX VOLT	MAX CURR	MAX VOLT	
			LBS.	LBS..	LBS.	LBS.	AMPS	VOLTS	AMPS	VOLTS	AMPS	VOLTS	
054	25# OUT'	0.1	0	55	55	127	44.1	27.8	-	-	0	28.6	
55	DWN & UP		0	64	64	231	403	21	-	-	3.1	27.6	
56	OUT		0	55	55	151	42	27.3	-	-	0.3	28.1	
57	DOWN		0	60	60	143	375	21.4	-	-	2.8	25.4	
58	UP		VOID	VOID	-	135	365	22.2	-	-	3.2	27.5	CTR 058
59	OUT		0	55	55	119	41	27	-	-	0.1	27.9	LOAD CELL
60	DOWN		0	64	64	119	360	21.4	-	-	1.6	23.3	WIRE
61	UP		323	68	365	215	375	21.7	-	-	3.6	27.6	LOOSE
62	IN		292	55	347	183	41	27.3	42.7	27.3	0	28.6	
63	OUT		250	55	305	183	41	27.1	-	-	0	28.6	
64	DOWN		0	55	55	119	VOID	-	-	-	1.8	24.8	
65	UP		0	64	64	159	368	21.1	-	-	2.9	25.8	
66	IN		0	55	55	135	42	27.1	44.7	27.2	0	28.6	

TABLE II 2 of 9

Internal Rescue Hoist Test Data

CTR	WEIGHT		MICRO SWITCH POS.	MAX. UPPER LIMIT LOAD (Compres-sion)	MAX. LOAD LINK (Tension)	MAX. COMPRES-SION LOAD + CORRES-PONDING TENSION LOAD	MAX. HOIST BOOM LOAD	HOIST WINCH MOTOR		BOOM ACTUATOR		TRACTION SHEAVE		COMMENTS
								MAX CURR	MAX VOLT	MAX CURR	MAX VOLT	MAX CURR	MAX VOLT	
				LBS.	LBS..	LBS.	LBS.	AMPS	VOLTS	AMPS	VOLTS	AMPS	VOLTS	
068	225#	DOWN	0.1	0	336	336	763	367	21.4	-	-	1.1	25.2	
69		UP		0	366	366	867	371	21.4	-	-	1.4	28.5	
70		DOWN		0	311	311	708	367	21.1	-	-	0.6	21.8	
71		UP		0	460	460	1074	372	21.8	-	-	0.9	27.4	
072	25#	DOWN	0.25	0	72	72	103	367	20.9	-	-	0.6	26	
73		UP		-708	77	772	279	379	21.5	-	-	2.4	21.5	
74		DOWN		0	60	60	119	365	21.1	-	-	0.6	22.6	
75		UP		0	60	60	151	368	21.1	-	-	2.0	26.2	
076	225#	DOWN	0.25	0	362	362	820	365	21.3	-	-	1.0	21.4	
77		UP		0	371	371	867	368	21.2	-	-	1.4	21.9	
78		DOWN		0	375	375	867	359	21.2	-	-	1.0	21.4	
79		UP		-229	396	458	915	360	21	-	-	0.9	22	

TABLE II 3 of 9

Internal Rescue Hoist Test Data

CTR	WEIGHT		MICRO SWITCH POS.	MAX. UPPER LIMIT LOAD (Compression)	MAX. LOAD LINK (Tension)	MAX. COMPRESSION LOAD + CORRESPONDING TENSION LOAD	MAX. HOIST BOOM LOAD	HOIST WINCH MOTOR		BOOM ACTUATOR		TRACTION SHEAVE		COMMENTS
								MAX CURR	MAX VOLT	MAX CURR	MAX VOLT	MAX CURR	MAX VOLT	
				LBS.	LBS..	LBS.	LBS.	AMPS	VOLTS	AMPS	VOLTS	AMPS	VOLTS	
081	25#	DOWN	INOP	0	60	60	111	361	21.4	-	-	0.4	21.4	
82		UP		-1230	81	1290	374	382	22.3	-	-	0.8	22.6	
83		DOWN		0	51	51	334	352	21.1	-	-	0.4	21.1	
84		UP		-573	68	628	239	361	21.2	-	-	0.4	22.4	
85	225#	DOWN	INOP	0	422	422	915	374	21	-	-	0.7	21	VOID DATA
86		UP		VOID	434	-	1432	432	21.6	-	-	0.9	21	DUE TO TRACE GOING OFF
87				N.G.	N.G.	-	-	-	-	-	-	-	-	OSC. ROLL
88		DOWN		VOID	336	-	772	341	21.5	-	-	0.5	21.5	
89		UP		VOID	498	-	1568	405	21.4	-	-	0.9	22.9	

TABLE II 4 of 9

Internal Rescue Hoist Test Data

CTR	WEIGHT		MICRO SWITCH POS.	MAX. UPPER LIMIT LOAD (Compression)	MAX. LOAD LINK (Tension)	MAX. COMPRESSION LOAD + CORRESPONDING TENSION LOAD	MAX. HOIST BOOM LOAD	HOIST WINCH MOTOR		BOOM ACTUATOR		TRACTION SHEAVE		COMMENTS
								MAX CURR	MAX VOLT	MAX CURR	MAX VOLT	MAX CURR	MAX VOLT	
				LBS.	LBS..	LBS.	LBS.	AMPS	VOLTS	AMPS	VOLTS	AMPS	VOLTS	
097	25#	DOWN	0.1	VOID	VOID	-	113	142	25.3	-	-	0.5	25.3	VOID DATA
98		UP				-	185	380	21 5	-	-	0.9	21.5	DUE TO
99						-	129	366	20.7	-	-	0.7	20.7	LOAD CELL
100		DOWN				-	121	364	20.7	-	-	0.7	20.7	UNPLUGGED
101	225#	UP	0.1	VOID	VOID	-	733	367	20.8	-	-	1.2	20.8	
102		DOWN				-	741	368	20.8	-	-	1.1	20.8	
103		UP				-	861	364	20.8	-	-	0.8	20.8	
104		DOWN				-	1433	388	21.5	-	-	1.3	21.5	

TABLE II 5 of 9

Internal Rescue Hoist Test Data

CTR	WEIGHT		MICRO SWITCH POS.	MAX. UPPER LIMIT LOAD (Compression)	MAX. LOAD LINK (Tension)	MAX. COMPRESSION LOAD + CORRESPONDING TENSION LOAD	MAX. HOIST BOOM LOAD	HOIST WINCH MOTOR		BOOM ACTUATOR		TRACTION SHEAVE		COMMENTS
								MAX CURR	MAX VOLT	MAX CURR	MAX VOLT	MAX CURR	MAX VOLT	
				LBS.	LBS..	LBS.	LBS.	AMPS	VOLTS	AMPS	VOLTS	AMPS	VOLTS	
112	225#	DOWN	0.1	0	450	450	958	376	20.7	-	-	0.8	20.9	
113		DOWN		0	338	338	676	370	20.8	-	-	1.3	21.6	
114		UP		0	621	621	1328	427	21.1	-	-	1.6	21.5	
115		DOWN		0	432	432	813	360	21	-	-	1.0	20.9	
116		UP		0	446	446	894	382	21.2	-	-	1.5	21.9	
117	25#	UP FAST	INOP.	-2188	72	2260	531	383	20.7	-	-	1.1	20.9	
118		UP SLOW		- 113	68	163	113	368	20.9	-	-	0.8	21.6	
119		UP FAST		- 154	72	208	113	364	20.9	-	-	0.8	20.9	
120		UP SLOW		- 308	90	358	193	381	21.4	-	-	0.8	21.6	
121		UP FULL		-2988	104	3028	652	429	22.1	-	-	0.8	22.1	BUMPED SKID

*NOTE: MAX COMPRESSION AND MAX. TENSION LOADS OCCUR AT THE SAME TIME.

TABLE II

Internal Rescue Hoist Test Data

CTR	WEIGHT	MICRO SWITCH POS.	MAX. UPPER LIMIT LOAD (Compression)	MAX. LOAD LINK (Tension)	MAX. COMPRESSION LOAD + CORRESPONDING TENSION LOAD	MAX. HOIST BOOM LOAD	HOIST WINCH MOTOR MAX CURR	HOIST WINCH MOTOR MAX VOLT	BOOM ACTUATOR MAX CURR	BOOM ACTUATOR MAX VOLT	TRACTION SHEAVE MAX CURR	TRACTION SHEAVE MAX VOLT	COMMENTS
			LBS.	LBS..	LBS.	LBS.	AMPS	VOLTS	AMPS	VOLTS	AMPS	VOLTS	
122	225# 'UP	INOP.	-1078	400	1231	982	366	20.7	-	-	0.8	21.6	
123	UP		-2834	428	3005	1377	429	22.1	-	-	1.0	22.7	
124	DOWN		0	374	374	974	358	21.1	-	-	0.6	21.1	JERKY
125	UP		-1571	638	1634	1433	399	21.8	-	-	1.1	21.8	
126	DOWN		0	387	387	853	356	20.7	-	-	0.7	21	
127	UP		- 113	810	923	1828	413	19.6	-	-	1.4	20.9	

*NOTE: MAX. COMPRESSION AND MAX. TENSION LOADS OCCUR AT THE SAME TIME.

TABLE II

Internal Rescue Hoist Test Data

CTR	WEIGHT		MICRO SWITCH POS.	MAX. UPPER LIMIT LOAD (Compres-sion)	MAX. LOAD LINK (Tension)	MAX. COMPRES-SION LOAD + CORRES-PONDING TENSION LOAD	MAX. HOIST BOOM LOAD	HOIST WINCH MOTOR		BOOM ACTUATOR		TRACTION SHEAVE		COMMENTS
								MAX CURR	MAX VOLT	MAX CURR	MAX VOLT	MAX CURR	MAX VOLT	
				LBS.	LBS..	LBS.	LBS.	AMPS	VOLTS	AMPS	VOLTS	AMPS	VOLTS	
132	225#	DOWN	0.1	0	298	298	624	380	21.2	-	-	1.1	21.2	
133		UP		- 61	392	453	813	386	21.1	-	-	1.2	21.1	
135		DOWN		0	264	264	568	375	21.3	-	-	1.9	26.3	
136		UP		N.G.	-	-	-	-	-	-	-	-	-	
137	400#	DOWN	0.1	0	601	601	1319	359	20.5	-	-	3.0	24.3	
138		UP		- 20	554	574	1240	366	20.3	-	-	1.5	21.5	
139		IN		- 30	448	478	1011	343	20.5	41	27.1	2:3	22.3	
140	400#	OUT	0.1	- 20	456	476	1026	40	27	-	-	0.2	27	
141		DOWN		0	597	597	1326	350	20.7	-	-	1.0	20.7	
142		UP		-152	771	923	1690	412	20.3	-	-	1.6	20.3	
143		IN		- 61	456	517	1042	40	27.1	-	-	0.2	27.1	

TABLE II 8 of 9

Internal Rescue Hoist Test Data

CTR	WEIGHT		MICRO SWITCH POS.	MAX. UPPER LIMIT LOAD (Compres-sion)	MAX. LOAD LINK (Tension)	MAX. COMPRES-SION LOAD + CORRES-PONDING TENSION LOAD	MAX. HOIST BOOM LOAD	HOIST WINCH MOTOR		BOOM ACTUATOR		TRACTION SHEAVE		COMMENTS
								MAX CURR	MAX VOLT	MAX CURR	MAX VOLT	MAX CURR	MAX VOLT	
				LBS.	LBS..	LBS.	LBS.	AMPS	VOLTS	AMPS	VOLTS	AMPS	VOLTS	
145	600#	DOWN	0.1	0	881	881	2013	366	20.8	-	-	1.5	20.8	
146		UP		- 62	1014	1076	2346	442	20.7	-	-	1.8	20.7	
147		IN		- 41	663	704	1546	40	27.4	41	28.4	0.1	27.4	
148		DOWN		0	813	813	1791	356	20.8	-	-	1.4	20.9	
149		UP		- 31	787	818	1815	370	20.9	-	-	1.6	20.9	
150		IN		- 31	783	814	1807	41	27.5	43	27.5	0.1	27.5	
153	400#	DOWN	INOP.	0	580	580	1240	366	20.9	-	-	1.3	20.9	
154		UP		- 30	840	870	1879	415	20.7	-	-	2.0	20.7	
155		DOWN		0	528	528	1192	368	21.1	-	-	1.4	21.1	
156		DOWN		0	443	443	971	362	20.7	-	-	1.2	20.7	
157		UP		-2815	660	3053	1934	434	21.9	-	-	1.6	21.5	

TABLE II

Internal Rescue Hoist Test Data

CTR	WEIGHT	MICRO SWITCH POS.	MAX. UPPER LIMIT LOAD (Compression)	MAX. LOAD LINK (Tension)	MAX. COMPRESSION LOAD + CORRESPONDING TENSION LOAD	MAX. HOIST BOOM LOAD	HOIST WINCH MOTOR MAX CURR	HOIST WINCH MOTOR MAX VOLT	BOOM ACTUATOR MAX CURR	BOOM ACTUATOR MAX VOLT	TRACTION SHEAVE MAX CURR	TRACTION SHEAVE MAX VOLT	COMMENTS
			LBS.	LBS..	LBS.	LBS.	AMPS	VOLTS	AMPS	VOLTS	AMPS	VOLTS	
158	400# UP	INOP.	-2825	891	3095	2227	423	22.3	-	-	1.7	21.3	FULL INTO
159	UP		-2602	920	2845	2077	423	19.6	-	-	2.0	20.1	LIMIT SWITCH
160			-2226	822	2469	2124	364	21.5	-	-	1.7	20	COLLECTIVE
													BOUNCE
162	600# DOWN	INOP.	0	878	878	1990	345	21	-	-	1.3	21	
163	UP		- 132	1270	1402	2993	407	21.8	-	-	2.0	21.8	
164	DOWN		0	643	643	1524	341	21	-	-	1.4	21	
165	UP		N.G.	N.G.	-	-	-	-	-	-	-	-	
166	600# UP	INOP.	-2368	1146	2825	2685	396	22.5	-	-	2.0	21.8	FULL INTO
167	UP		INST.	1278	-	2985	395	21.6	-	-	1.6	20	LIMIT SWITCH
			FAILED										
	*NOTE: JERKY CONDITIONS												

APPENDIX IV

UH-1N HELICOPTER RESCUE HOIST CABLE TEST

1. Background - Recent flight operations have produced a condition of significant reduction in flight safety on helicopter rescue systems. The hoist cables have been experiencing failures in the field. This cable is not qualified to a military specification but is part of a package with the hoist assembly, developed to contractor requirements.

2. Purpose - To determine the wear, fatigue properties, and breaking strength of 3/16 inch 19 x 7 spin resistant cables that were being used on the UH-1N hoist, and other cable samples purchased according to military specification requirements.

3. Test Equipment - The test apparatus consisted of:

a. A UH-1N hoist mounted 27 feet off the floor (see Fig 1)

b. A fabricated fatigue machine capable of testing two cables simultaneously (see Fig 2)

c. A Baldwyn tensile test machine that was modified to permit cable samples to have one free end (by means of a swivel) for free rotation of the cable during the tensile test.

4. Test Site - The test was performed at the Flight Dynamics Laboratory Structural Test Facility, Building 65, Wright-Patterson AFB, Ohio

5. Test Cables - The test cables were procured from two cable manufacturers and are listed as Type A, B, C, and D for identification purposes only.

Type A - Military specification cable (MIL-W-83140)

Type B - Non-military specification cable (degreased)

Type C - Proposed militar specification cable (MIL-W-83140)

Type D - High strength 3700 pound non-military specification cable (degreased)

All 3/16 inch 19 x 7 cables are spin resistant and were constructed as per MIL-W-83140. The inner cable strand is left-hand lay and the outer strand is right-hand lay with a pitch producing approximately 120 lays per linear foot.

6. Test Procedures - In order to determine the wear and fatigue characteristics of each type of cable under actual rescue hoist operation, an operational cycle hoist test, a fatigue cycle test, and an ultimate breaking strength test were utilized.

a. Operational Cycle Hoist Test - The operational hoist test was designed to simulate actual operation under service conditions. The hoist was mounted such that a free-fall drop of 27 feet was available below the hoist. A cable length of 100 or 250 feet was mounted on the hoist for each cycling test. A cycle on the hoist consisted of raising a specified weight approximately 12 feet from the floor, stopping abruptly, then lowering the weight 10 feet, stopping again, then lowering to the floor.

The reason for the described cycling procedures was to test the cable and not the hoist. It performed as stated to induce transient tensions in the cable by stopping the load suddenly at the two stated positions, and by sudden load pick-ups starting with a slack cable. The maximum measured transient load factor did not exceed 2.05 G as derived from tensiometer readouts.

Tests performed on the hoist are as follows:

One of Type A cable	50 cycles	with	400 lb load
One of Type A cable	100 cycles	with	400 lb load
One of Type A cable	200 cycles	with	400 lb load
One of Type A cable	400 cycles	with	400 lb load
Four of Type A cable	800 cycles	with	400 lb load
One of Type A cable	2000 cycles	with	600 lb load
One of Type B cable	2000 cycles	with	600 lb load
One of Type C cable	2000 cycles	with	600 lb load

Test cycles of Type A, 50 cycles thru 800 cycles at 400 lb load, showed no residual loss in breaking strength (see App II). For results of 2000 cycles at 600 lb load, see Table 1.

Upon completion of the test cycles performed on the hoist, the test cable was measured and marked (see Fig 1) into tensile test sections, then removed from the hoist system. Some of the working sections of the cable were shorter than others, although no section exceeded three feet in length. These sections were tensile tested and the results are recorded in Table 1. Four baseline samples for each cable type are averaged and included for comparison purposes in Table 1. Note that the standard deviation of the baseline samples was quite low. The strength of the baseline samples was almost constant.

b. Fatigue Cycle Test - The fatigue cycle test was incorporated since much of the motion of the cable under hoist operation is of a bending and flexing nature, thus making it susceptible to fatigue failure. The fatigue

test was performed on a specially designed machine as shown in Fig 2. This machine performs the same functions as the fatigue machine as specified in the military specificatin with the exception that a swivel and tensiometer were incorporated so that the test cables could rotate freely and to enable the accurate recording of loads. It was determined that a cable load of 200, 400, 500, and 600 pounds should be applied to the test cable since this is the range of design loads for the hoist system. It was also determined that the test cables should be subjected to 100,000 reversals, or 50,000 cycles, since this potentially provided an appreciable reduction in the breaking strength of the original contractor's supplied cables. Upon completion of the fatigue test, which was determined by completion of 50,000 cycles, complete failure of cable, or the separation of the inner strands of the cable, the cables were marked and sectioned into three-foot specimens and removed for tensile testing. The number of cycling tests and breaking strengths are recorded in Table 2.

The concept of testing the cable on the hoist and on the fatigue cycle machine was to determine the loss in strength and the wear and deterioration of the cable while they are being worked under conditions simulating actual operations. In order to obtain an initial breaking strength for the specimens, four 3-foot specimens of each cable were tensile tested without any previous working. These four breaking strengths were averaged to obtain a value for comparison against the strength of those cables completing fatigue tests. The standard deviation of the baseline samples was again quite low.

c. Breaking Strength Test - The test cables were prepared for tensile testing by swaging MS 20664-6 ball terminals on both ends. The cables were then attached to the tensile machine by inserting one end into a fixture and placing the cable over a 90° pulley and inserting the other ball end into a swivel. In every test, the worn cables broke at positions other than the ball fittings (see Fig 3).

A listening device was incorporated with each tensile test specimen to detect occurrence of broken wires in the specimen (see Fig 3). The amount of deflection was measured on each specimen and was found to be between 1/2 to 2 inches. It was found that the military specification cable exhibited twice as much stretch than the other cables tested.

7. Explanation of Figures - Fig 4 shows the difference in cable breaking strength due to changes in tensile test attachment of the three-foot test sample. For Type A, there is no appreciable difference in fixed-end and free-rotation end method. The other three types demonstrate a considerable reduction in breaking strength using free-rotation end method in lieu of the fixed-end method. It is concluded that most cable types are considerably weakened by the free-rotation end method.

Figure 5 shows the average total number of cycles achieved by each type of cable at specific tension load levels. Types A and C completed 50,000 cycles under all loads without a failure, whereas B and D failed prematurely at the indicated number of cycles.

Figure 6 (photograph A) shows MIL-W-83140 (Type A) cable that has been subjected to 50,000 cycles under 400 pounds tension.

Figure 7 (photograph B) shows Type B cable that has been subjected to 22,000 cycles under 400-pound load.

Figure 8 (photograph C) shows new, unused Type A cable.

8. Results and Recommendations -

a. A review of Tables 1 and 2 and Figures 4 and 5 indicates that cables meeting Military Specification MIL-W-83140 exhibited the best properties of strength and fatigue life of the cables tested. In some cases, certain types were unacceptable. It is ASD/ENFL's opinion and recommendation that only cables qualifying to MIL-W-83140 be used on the UH-1N helicopter rescue hoist system and that these cables should be changed every 1,500 cycles, provided that the cable is not two-blocked due to an inoperative up-limit switch. The present MIL-W-83140 will be revised to include free-end breaking strength test and several other improvements developed during this test. The 1,500 cycle life is based primarily on the small strength degradation observed during the 2,000 cycle/600 pound hoist test (Table 1). A 500 cycle reduction from that tested is considered necessary to account for cable strength variance due to manufacturing, etc, and the fact that the cable is non-inspectable.

b. It is also recommended that all cables be lubricated as specified in the military specification. During the breaking strength tests, the degreased cables (Fig 7) tended to explode at failure (most likely due to notching and work-hardening), whereas the lubricated cables (Figures 6 and 8) broke with much less severity. Of all cables tested, cable A exhibited the most uniformity at failure; that is, the inner core strands consistently broke together rather than separately.

c. Test data and photos show that an external cable inspection will not provide evidence of impending cable failure because inner-core failure occurs first. The external inspection remains desirable, however, to reveal outer wrap wire breakage due to snags, bird-caging, etc.

d. The fatigue characteristics (strength degradation) of the cables tested appeared to be influenced to a large degree by cable ductility, cable manufacturing methods, and individual strand properties in lieu of initial breaking strength. Cables A and C showed a minimum strength reduction after endurance testing, while cables B and D failed to complete the testing at higher tension loads. It is interesting to note that cables B and D were also the cables which had the higher initial breaking strength when tested with fixed end attachment. The conclusion may be drawn that a higher initial cable breaking strength which sacrifices ductility tends to show poor fagigue life capabilities.

e. The method of breaking cables as presently contained in MIL-W-83140 is not representative of true cable strength in the UH-1N hoist applications. Our testing used a free end set-up which showed a decrease in cable strength of approximately 10-25 percent in some cases, which is considered significant. This phenomenon is characteristic of non-rotating or spin resistant cable due to its construction in that a certain amount of torque is developed when the cable is under a tensile load. If one end of the cable is free to rotate, a torque unbalance occurs which tends to tighten the inner strand lay and unwrap the outer lay strands. If the unbalance is significant, the result is a large decrease in ultimate breaking strength. The degree of torque unbalance generated varies directly with tensile load and appears to be primarily dependent on the ability of the contractor to obtain a uniform and stable torque-balanced cable construction during manufacturing. Consequently, since each contractor uses a unique set of wire sizes, wire material, strand lays, and rope lays, somewhat different characteristics are obtained, depending on the source of the cable. Figure 4 readily shows these differences.

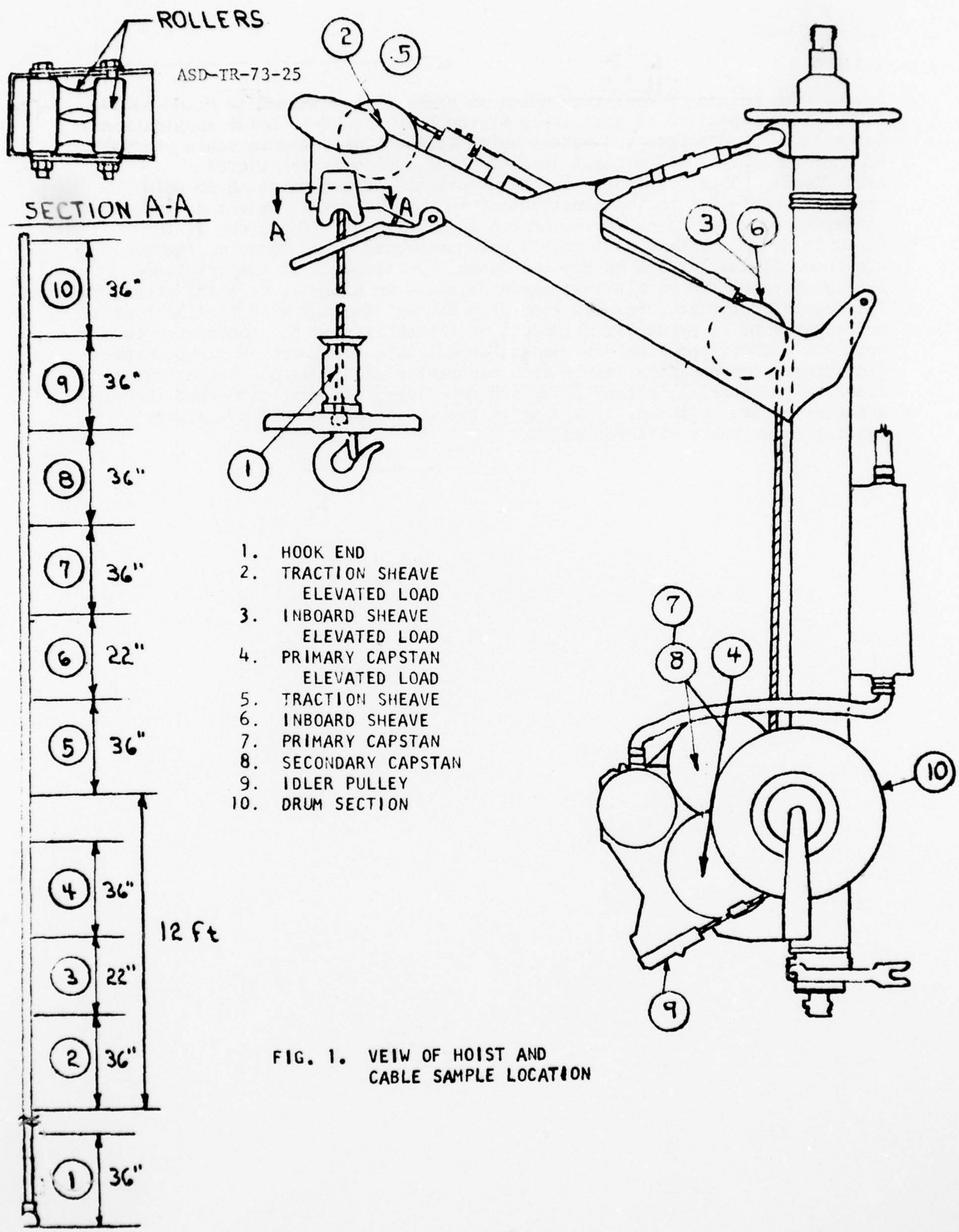


FIG. 1. VEIW OF HOIST AND CABLE SAMPLE LOCATION

FIG.2 ENDURANCE TESTING MACHINE

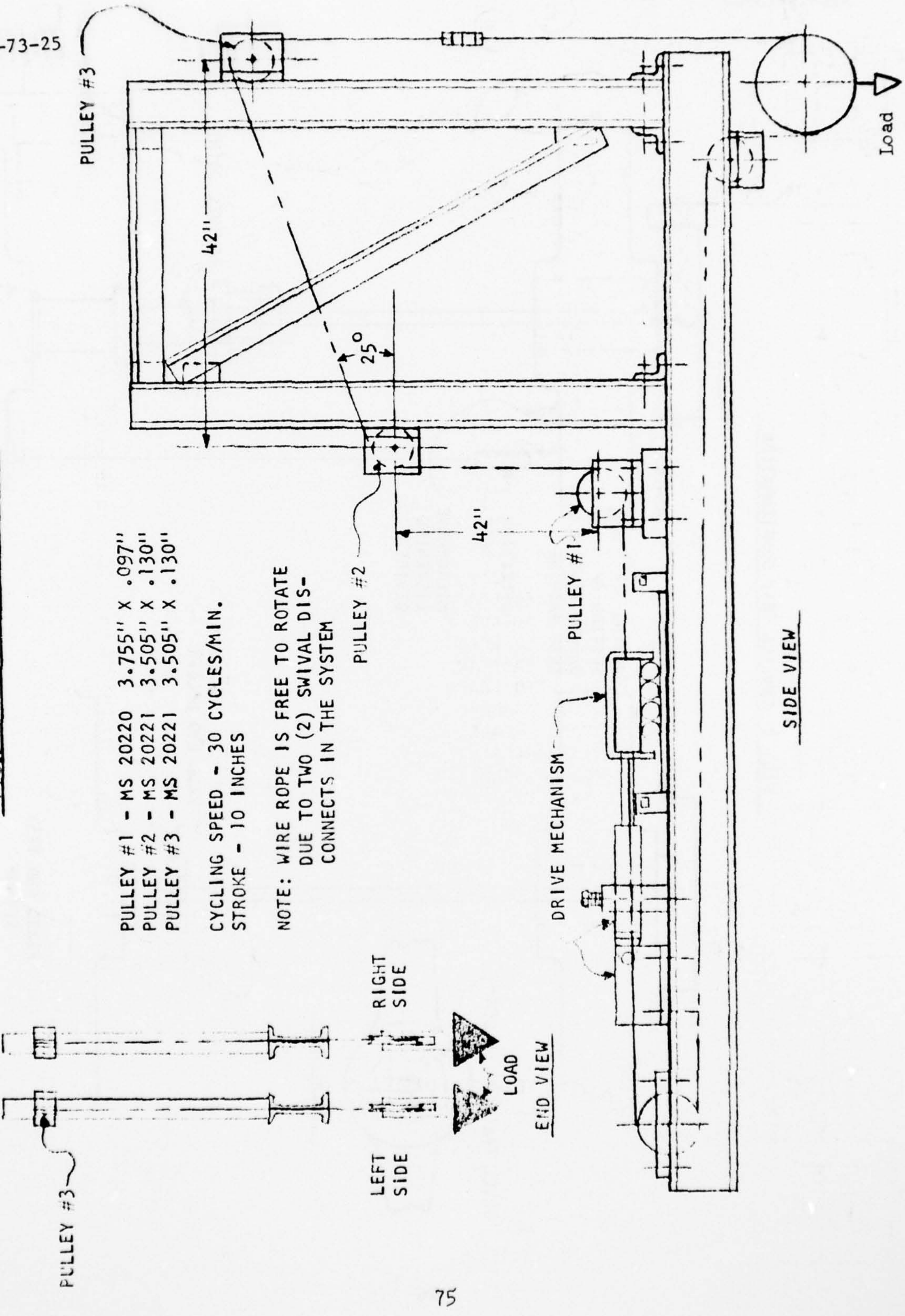
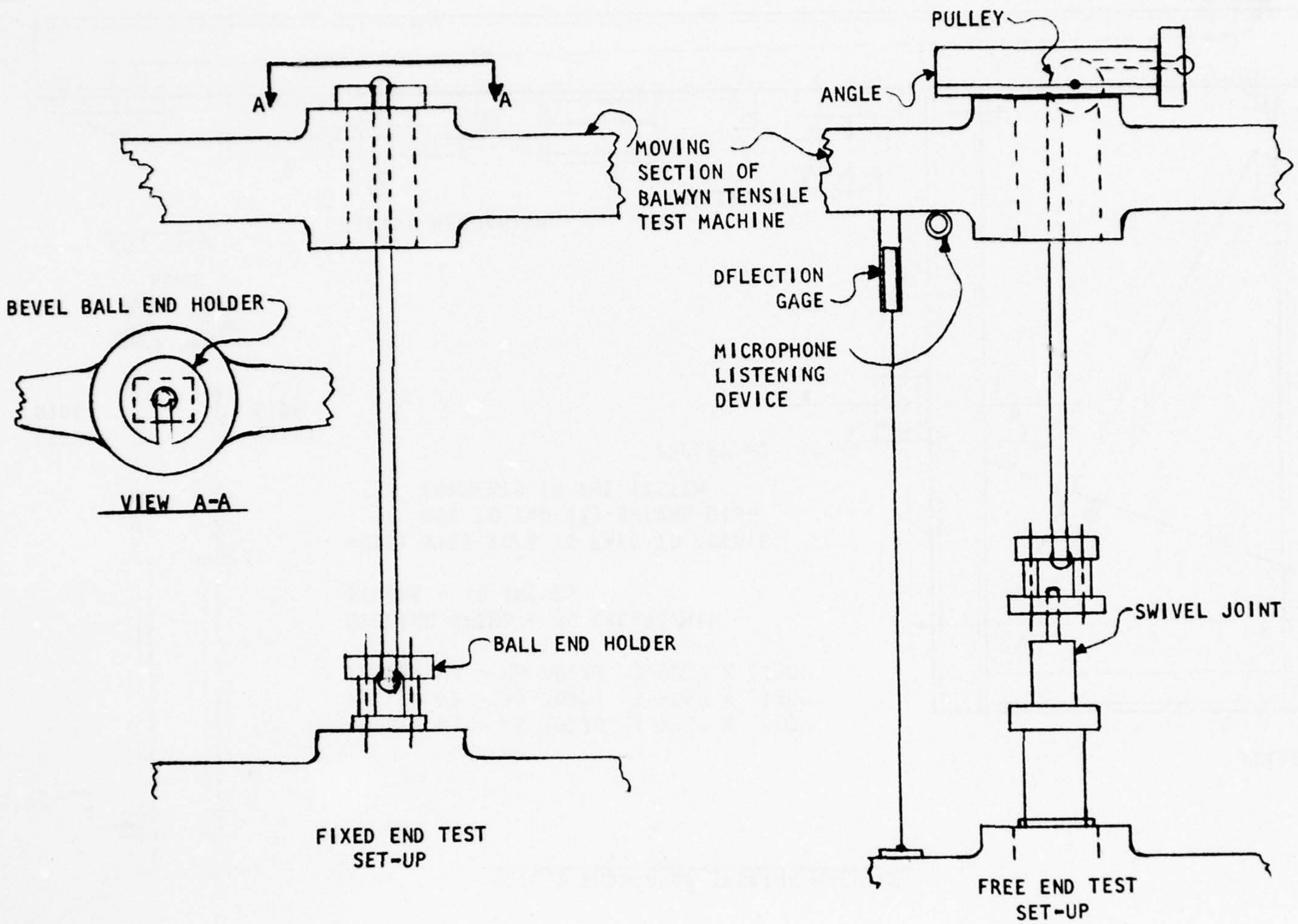


FIG. 3 TENSILE TEST CONFIGURATION



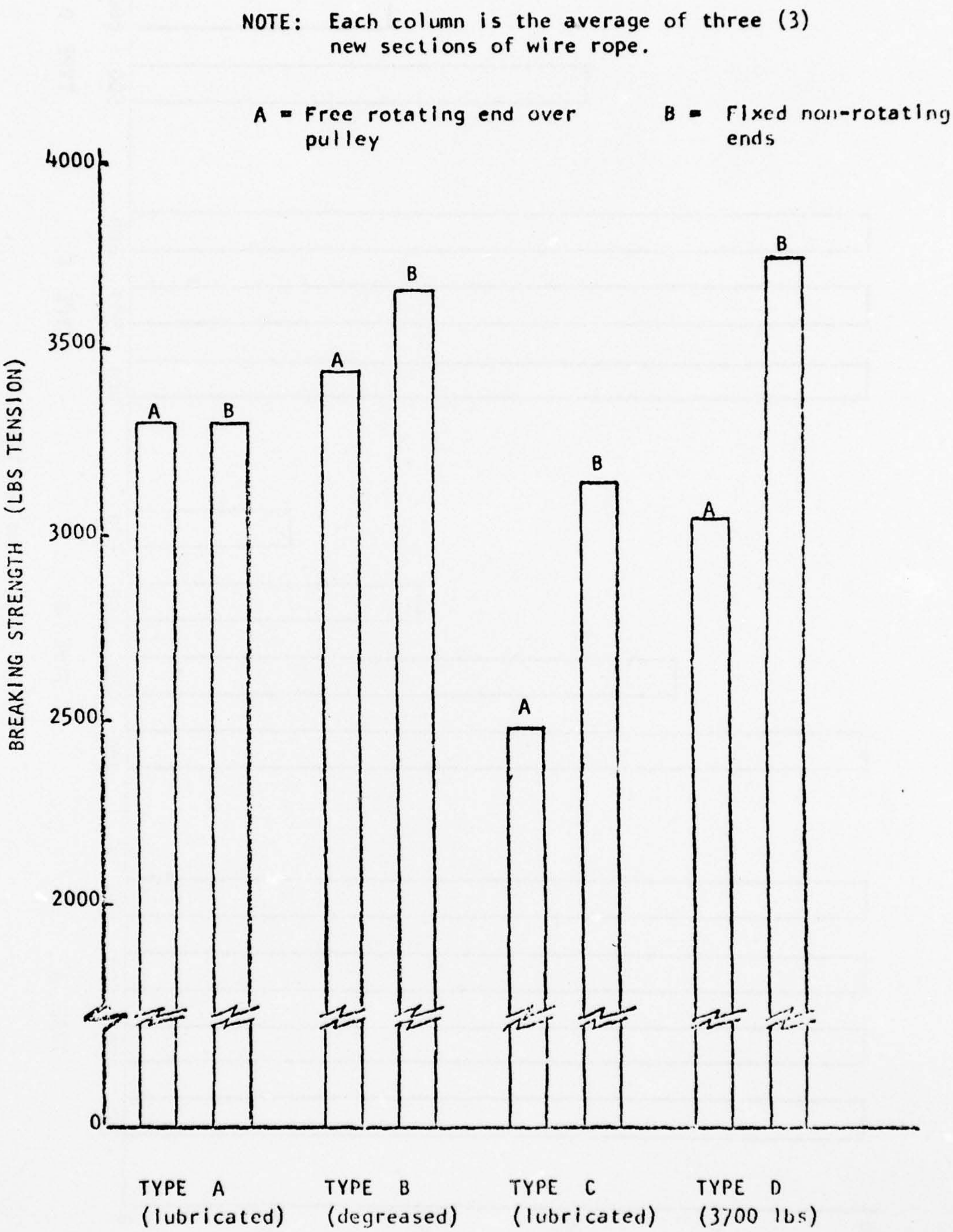


Figure 4 COMPARISON OF CABLE BREAKING TECHNIQUES

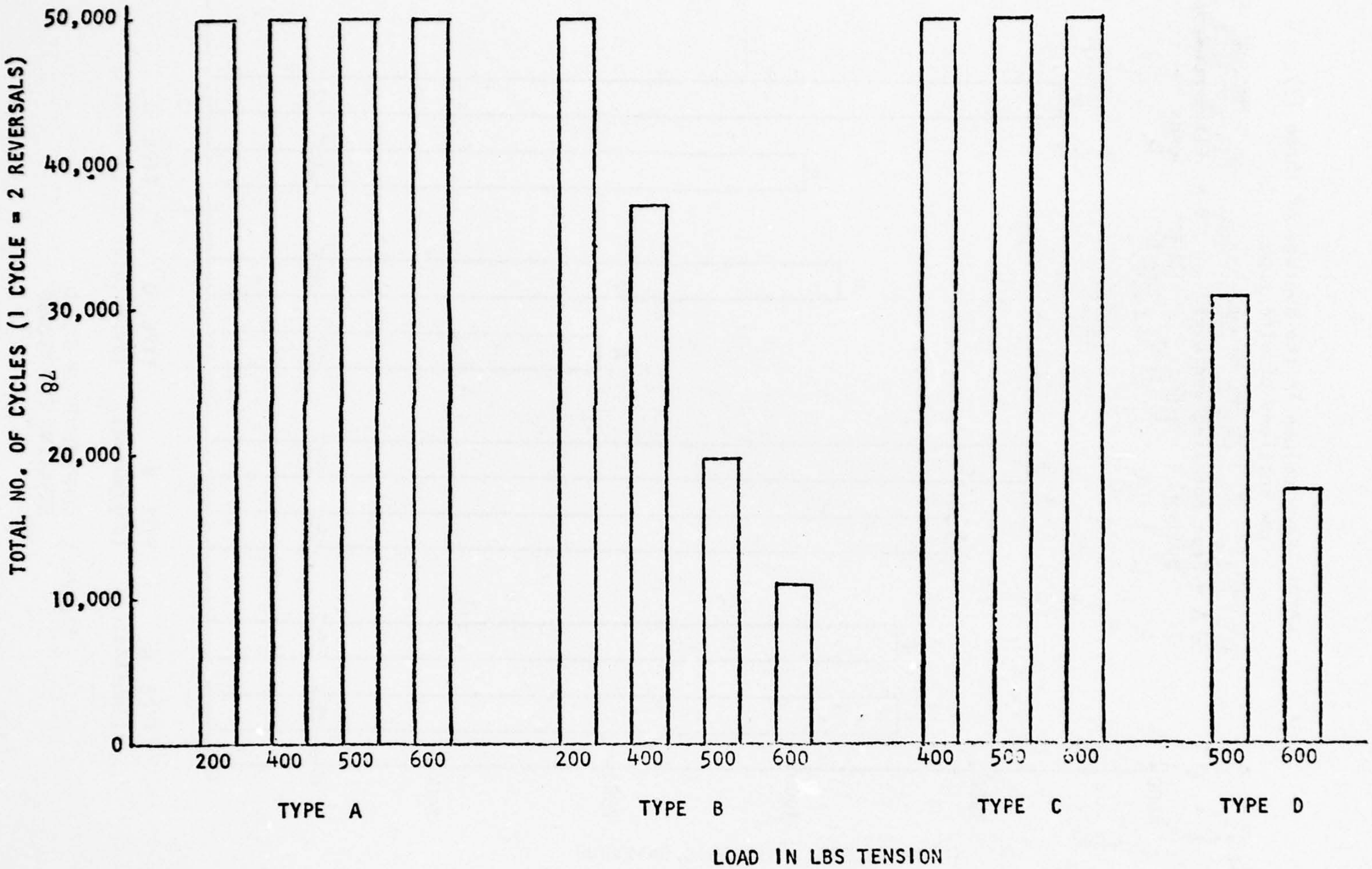


Figure 5 TOTAL NUMBER OF CYCLES VS LOAD IN TENSION AND TYPE

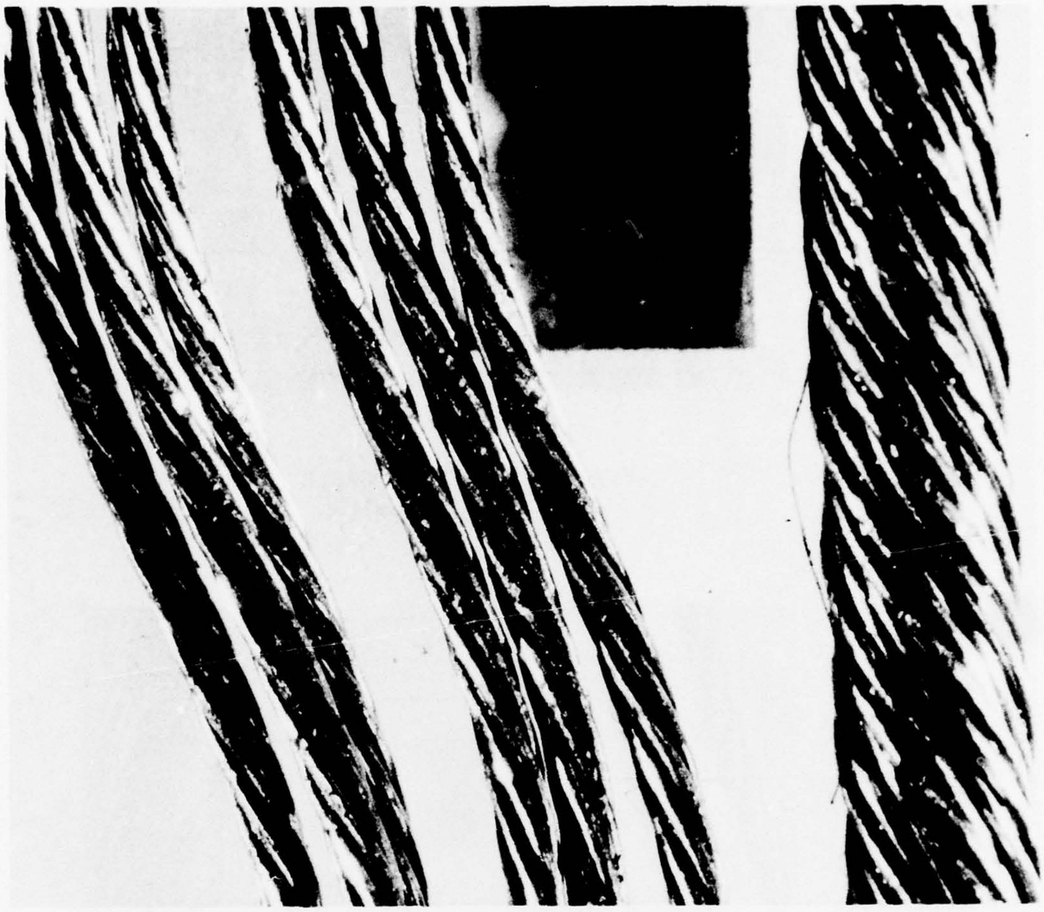


Figure 6 TYPE A CABLE
(50,000 Cycles)

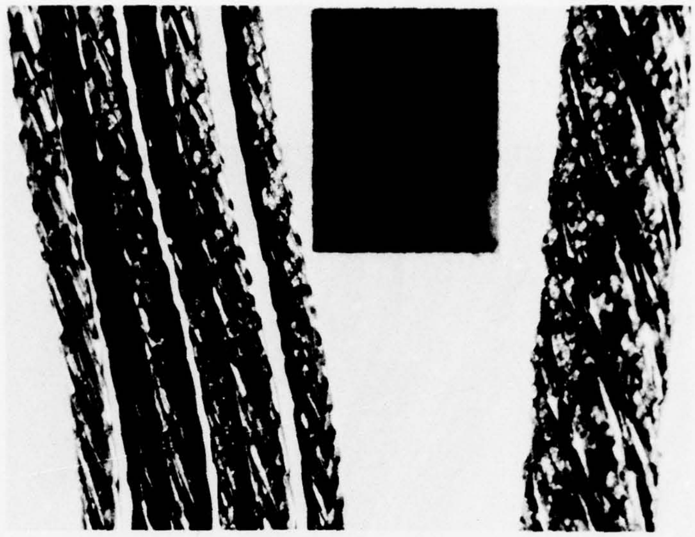


Figure 7 TYPE B CABLE
(22,000 Cycles)

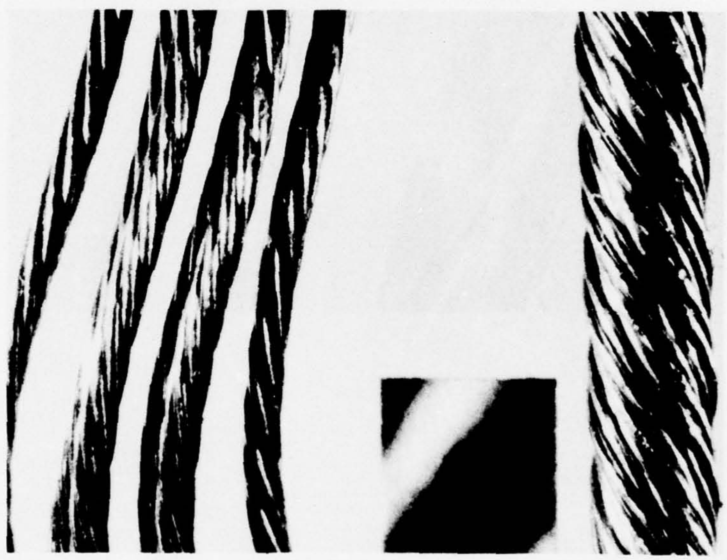


Figure 8 TYPE A CABLE
(0 Cycles)

TABLE NO. 1

2,000 CYCLE TESTING ON HOIST
600 LB LOAD

CABLE SPECIMEN LOCATION	BREAKING STRENGTH					
	TYPE A		TYPE B		TYPE C	
	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER
1. HOOK END	3325	3325	3525	2475	2475	2270
2. TRACTION SHEAVE ELEVATED LOAD	"	3225	"	2685	"	2570
3. INBOARD SHEAVE ELEVATED LOAD	"	3310	"	2930	"	2430
4. PRIMARY CAPSTAN ELEVATED LOAD	"	3310	"	2640	"	2440
5. TRACTION SHEAVE	"	3225	"	2950	"	2360
6. INBOARD SHEAVE	"	3310	"	2570	"	2530
7. PRIMARY CAPSTAN	"	3300	"	2470	"	2265
8. SECONDARY CAPSTAN	"	3270	"	3030	"	2265
9. IDLER PULLEY	"	3225	"	2540	"	2590
10. DRUM SECTION	"	3270	"	2480	"	2315
	SD = 5		SD = 25		SD = 30	

NOTE: Type D cable not subjected to this testing due to limited test time available and its relatively poor endurance characteristics (Fig 3).

TABLE NO. 2

ACCUMULATED DATA SHEET

P.P. = PULLEY POSITION

CABLE TENSION (lbs)	TYPE A						TYPE B					
	SPECIM. TEST NO.	TOTAL NO. CYCLES	BREAKING STRENGTHS (lbs)				SPECIM. TEST NO.	TOTAL NO. CYCLES	BREAKING STRENGTHS (lbs)			
			BEFORE TEST	P.P. 1	P.P. 2	P.P. 3			BEFORE TEST	P.P. 1	P.P. 2	P.P. 3
200	1 L	50,000	3330	3275	3260	3340	3 L	50,000	3540	3400	2950	3500
	2 R	50,000	3330	3280	3240	3310	4 R	50,000	3540	3070	2925	3600
400	15 L	50,000	3330	3165	2990	3090	5 L	37,132	3544	2400	1975	3475
	16 R	50,000	3330	3000	2875	2940	6 R	37,132	3544	3350	FAILED	1460
400	27 L	46,143*	3307	3265	3190	3200	13 L	37,469	3479	2840	2250	2365
	28 R	46,143	3307	3200	3075	3140	14 R	37,469	3479	3050	FAILED	2830
500	17 L	50,000	3258	3255	2990	3030	9A L	16,607	3500	2885	1915	2505
	18 R	50,000	3258	3260	3265	3290	10A R	16,607	3500	2870	FAILED	3230
500	19 L	50,000	3330	3245	3165	3125	9 L	20,600	3544	2775	2900	2825
	20 R	50,000	3330	3260	3300	2815	10 R	20,600	3544	2815	1350	3360
500							11 L	23,606	3490	3150	2340	2500
							12 R	23.606	3490	2875	2675	625
600	21 L	50,000	3292	3225	3225	3090	25 L	11,264	3482	2530	FAILED	2250
	22 R	50,000	3292	3290	3110	3000	26 R	11,264	3482	2830	1400	2280
600	23 L	50,000	3299	3215	2665	2915	35 L	11,733	3522	2555	2465	1470
	24 R	50,000	3299	3270	2830	2750	36 R	11,733	3522	2480	1740	FAILED
600							35A L	9,250	3522	2585	2840	2870
							36A R	9,250	3522	2780	FAILED	2880

* STOPED PREMATURELY DUE TO A HYDRAULIC FAILURE IN THE SYSTEM

TABLE NO. 2 CONT'D

ACCUMULATED DATA SHEET

P.P. = PULLEY POSITION

CABLE TENSION (lbs)	TYPE C						TYPE D					
	SPECIM. TEST NO.	TOTAL NO. CYCLES	BREAKING STRENGTHS (lbs)				SPECIM. TEST NO.	TOTAL NO. CYCLES	BREAKING STRENGTHS (lbs)			
			BEFORE TEST	P.P. 1	P.P. 2	P.P. 3			BEFORE TEST	P.P. 1	P.P. 2	P.P. 3
200												
400	39 L	50,000	2502	2425	2710	2585						
	40 R	50,000	2502	2515	2560	2345						
400												
500	31 L	50,000	2502	2440	2345	2400	43 L	30,812	3066	2960	2280	FAILED
	32 R	50,000	2502	2500	2495	2330	44 R	30,812	3066	2940	2960	2620
500	33 L	50,000	2502	2280	2615	2270						
	34 R	50,000	2502	2450	2230	2590						
500												
600	29 L	51,200	2502	2320	2540	2465	41 L	17,503	3066	3050	2850	2710
	30 R	51,200	2502	2280	2265	2470	42 R	17,503	3066	3025	FAILED	3150
600	37 L	50,000	2502	2340	2270	2295						
	38 R	50,000	2502	2430	2295	2285						
600												

TABLE NO. 3

COMPARATIVE TEST RESULTS (SUMMATION)

50,000 CYCLES ON FATIGUE TEST MACHINE

CABLE TENSION (LBS)	MIN. BREAKING STRENGTH (LBS)											
	TYPE A			TYPE B			TYPE C			TYPE D		
	No of Samples	Before	After	No of Samples	Before	After	No of Samples	Before	After	No of Samples	Before	After
200	2	3330	3240	2	3540	2925	-	-	-	-	-	-
400	4	3307	3140	4	3479	F-1	2	2502	2345	-	-	-
500	4	3330	2815	4	3500	F-2-3-4*	4	2502	2230	2	3066	F-5*
600	4	3299	2665	4	3482	F-6-7-8*	4	2502	2265	2	3066	F-9*

NOTES

F-1 Failed @ 37,469 Cycles

F-2 Failed @ 16,607 Cycles

F-3 Failed @ 20,600 Cycles

F-4 Failed @ 23,606 Cycles

F-5 Failed @ 30,812 Cycles

F-6 Failed @ 11,264 Cycles

F-7 Failed @ 11,733 Cycles

F-8 Failed @ 9,250 Cycles

F-9 Failed @ 17,503 Cycles

*Remaining Cable Sample Removed With Last Failure.

APPENDIX V

ELECTRO-MECHANICAL TEST

1. Purpose - The purpose of this test was to determine the engineering adequacy and capability of the present hoist system configuration to perform and operate satisfactorily within actual life support parameters as well as the training missions performed at Fairchild AFB and Homestead AFB. In addition, the tests provided information for the projected life of equipment, as well as necessary data for modifications necessary to provide the Air Force with a suitable hoist system for satisfactory operation within certain mission parameters. This test examined all hoist components with the exception of the cable.

2. Electro-Mechanical Test Procedure for UH-1N Rescue Hoist -

a. Scope - The test plan for the hoist subsystem entailed visual examination and functional testing of the hoist subsystem which consists of the following major assemblies:

(1) BL-8300 winch

(2) BL-13800 traction sheave

(3) BL-8420 control box

(4) BL-8430 control pendant

(5) Post and boom assembly

(6) Electrical cabling and circuitry

b. Test Site - Laboratory testing was conducted at AFFDL's facility at Wright-Patterson AFB. All tests were monitored by the Design Review Team with support from the Breeze Corp (hoist vendor).

c. Test Procedure - The hoist system was mounted by AFFDL personnel approximately 27 feet off the floor, on a suitable fixture which allowed the team ready access to all hoist hardware during the test program. This feature was necessary to permit visual inspection of system hardware, to change or modify parts, adjust equipment, as well as collect test data. The hoist system was mounted so as to provide simulation of an aircraft installation as nearly as practicable. Twenty-eight volts DC power with minimum 150 ampere service for hoist system operation was provided.

(1) Recording of Data - Temperatures, measured by instrumenting the system with thermocouples, were recorded. The following points were monitored:

(a) Hoist motor case temperature (approx 170°F to 185°F)

(b) Hoist gear box oil temperature (approx 120°F to 200°F)

(c) Hoist motor brush temperature (approx 200°F to 375°F)

(2) Monitoring Hoist Performance - The following data were recorded continuously on a strip chart recorder:

(a) Hoist motor current

(b) Hoist motor voltage

(c) Control box relay voltage

(d) Tension load cell

(e) Compression load cell

(f) ± 5 G accelerometer

(g) Turnbuckle strain

(h) Cable velocity

(i) Up limit switch actuation

The following data were recorded when necessary, using an ammeter or voltmeter:

(a) Line current

(b) Line voltage

(c) Control box relay current

(d) Actuator current

(e) Actuator voltage

(3) Mechanical Data - A load cell tensiometer was installed between the hook assembly and test weight to record load forces that are imposed upon the hoist cable when cable speed is accelerated in such a manner as to ram the hook bumper assembly into the stop or up-limit switch. These load forces ranged between 50 and 3,000 pounds.

(4) Functional Tests - With a 25-to 30-pound load (forest penetrator) attached to the hook assembly, the hoist was operated for 10 complete cycles to insure satisfactory operation of the hoist system. The

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system was operated by the pendant control and, after each second cycle, the boom was swung to the out and in (stowed) position to insure satisfactory operation of boom controls and actuator.

d. Life Test - The complete hoist system was subjected to 2950 cycles (simulated school pick-ups) as specified herein. A portion of the life test was conducted to simulate beeping of the hoist hook (jogging), but all cycles completed were considered as part of the life cycle total count. One complete hoist operation (reel-out and reel-in) in either mode was considered one test cycle.

(1) Mode I

(a) Thirty feet of cable was reeled out with a load of 250 pounds applied to the hoist hook. The cable speeds averaged at least 75 fpm and were obtained by operating the pendant control. Average cable speed during slow-down periods, unless otherwise specified at each extreme of cable travel, was approximately 25 to 50 feet per minute.

(b) The hoist was stopped for 15 seconds maximum.

(c) Thirty feet of cable was reeled in with a load of 250 pounds.

(d) The hoist was stopped and accelerated to maximum cable speed so that hook bumper slammed into the up-limit switch.

(e) The hoist was stopped. Off time was determined by peak temperature measurements from motor (motor brush 450°F, motor case 185°F maximum, or gear box 200°F).

(f) The above procedures were repeated for a total of 800 cycles.

(2) Mode II

(a) The procedures of Mode I were repeated except that no load was applied to the hook assembly for a total of 500 cycles.

(3) Mode III

(a) The procedures of Mode I were repeated except that, as the hook assembly neared the reel-in extremity, the cable travel speed was slowed down to allow "beeping in" of the hook until the stop limit switch was activated. The beeping operation started at least six inches prior to hook bumper assembly contact with the stop limit switch. This test was repeated for 200 cycles.

(4) Mode IV

(a) The procedures of Mode I were repeated except that a weight of 600 pounds was used for a total of 1,450 cycles.

(5) Boom Operation

(a) During the life tests (paragraph d above), the boom was swung to the full out and in position to simulate a rescue mission. This operation was executed every fourth cycle of the life test program and was operated by the pendant control boom switch.

e. Rescue Hook Assembly and Forest Penetrator Compatibility - The forest penetrator was attached to the hook assembly in the normal manner. The penetrator was suspended approximately one foot from the floor, and the device was manually rotated about the hook throat area attempting to execute a "hang up" of the penetrator eyelet within the hook assembly.

3. Testing - An overhauled zero time hoist assembly was received from the Breeze Corp and instrumented as per the test procedure (Section II). The checkout cycles were run and testing began.

a. Control Pendant - At the 125th cycle, the hoist continued to operate for a few seconds after manual release of the control switch. It was suspected that this was caused by the control switch "sticking" and not returning to the center off position. This again happened at cycle 1,150, but otherwise did not reappear. This was considered a random type failure.

b. Capstan - A cyclic knocking sound, similar to the noise encountered during the interim testing (App II, and paragraph 5 of this appendix), began at cycle 1,000. The noise again appeared to be coming from the secondary capstan. This noise continued through the 1,500th cycle when it ceased. The center section of the cable failed on cycle 1,551. A new cable was installed and testing continued. The knocking sound reappeared after 1,600 cycles.

At 1,771 cycles, a second cable failure occurred. At this time it was noticed that the steel rim, which is heat fitted over the secondary capstan, had slipped laterally and was wearing against the cable guard. The cable guard wear was bevel shaped. This is to say that the top of the guard was much less worn than the lower portion. The upper bear claw was also badly worn. Testing was halted and the hoist disassembled to determine the cause of the cable failures.

Disassembly revealed no concrete evidence as to the root cause of the hoist failure. It was determined, however, that the cable failures were caused by the steel capstan rim slipping axially and pinching the cable between the rim and the upper bear claw. (These two cable failures were extremely unusual in that the outer cable strands showed no visible signs of damage. Only the inner cores had failed.) The beveled cable

guide would seem to indicate that the capstan was cocked or not perpendicular to the side plate/cable guide assembly. It had been noticed that the side plate flexed in and out during operation under heavy load. However, no cause for the axial slippage or the clicking noise could be determined.

A new capstan was installed and testing resumed. The new capstan was marked so that radial rim slippage could be detected. After approximately 200 more cycles, the rim had slipped 1/16" radially and was again making the clicking noise. The rim did not slip axially for the remainder of the testing, but the clicking noise persisted. At 2,950 cycles, the end of the test, the cable guide was slightly worn by the steel rim.

c. Motor Stall - After disassembly of the hoist at cycle 1,771, another problem started to occur. At cycles 1771, 1982, 1983, 2233, 2444, 2659, and 2950, the hoist motor "stalled" while lifting the 600-pound load. The stall was accompanied in the latter cases by oil smoke from the motor and/or gear box. The control box and pendant were replaced without improvement. The motor stalled, smoke was emitted, and then it started up again.

Figure 1 depicts strip chart recorder data for cycles 2800, 2850, and 2900. The motor amperage and voltage (channels 1 and 2) appear erratic compared with Figures 2 and 3, which depict cycles 350, 400, 450, 800, 850, 900, and 950.

The motor case side plate was removed and the presence of appreciable quantities of oil detected. Thus it appeared that oil contamination was causing the motor stalls.

d. Oil Leak - At 1,850 cycles it was noticed that the hoist was loosing oil from the gear box. Oil was added at 2,051 cycles. It is believed that the disassembly at cycle 1,771 caused this oil leak problem.

e. Two Block - At the completion of the 2,950 electro-mechanical test cycles, a short test was run to determine the effect of impacting the hook into an inoperative up-limit switch. Approximately 2,600 pounds of cable tension was generated at each impact. Four tests were run. New MIL-W-83140 (Type A) cables were used. The four cables broke after 35, 35, 17, and 25 impacts. There was no weight on the cable. Figure 4 depicts one of these tests showing the impact loads.

f. Jogging - Other tests were accomplished to determine the effect of "jogging" the hoist with various loads (Fig 5). This was accomplished by rapidly flipping the hoist on and off, causing the lead weight to jerk or bounce. The cable tension results are given in App II, Tables 1 and 2. Flight tests (App III) were also run to determine these loads in flight. At higher loads (i.e., 600 pounds) the helicopter experienced severe gyrations during hoist jogging. The helicopter acts as a shock absorber at high loads, reducing the G's on the cable. Thus, at 600 pounds the maximum

jogging cable tension was 1,278 pounds (2 G's), but at 225 pounds it was 810 pounds (over 3 G's). No cable tension higher than 1,300 pounds was achieved on a completely functional hoist.

g. Penetrator Cocking - The forest penetrator was attached to the hook and attempts were made to cock it in the hook throat. It was confirmed that this hang up occurs readily and would be severely detrimental to the cable, due to the resulting kinking action at the cable ball end.

h. Data Recording - An eight channel strip chart recorder (Fig 6) was used to record data. The following settings apply to Figures 1, 2, 3, 4, 5, and 7, except where noted:

Channel 1 - motor current, 2 amperes per division

Channel 2 - motor voltage, 1 volt per division

Channel 3 - relay voltage, 1 volt per division

Channel 4 - tension load cell, 25 pounds per division

Channel 5 - compression load cell, 20 pounds per division

Channel 6 - ± 5 G accelerometer, 0.1 G per division

Channel 7 - turnbuckle strain, 10 micro strain per division

Channel 8 - cable velocity (traction sheave rotation, each revolution is 11.75" of cable travel)

The paper speed was 1 mm per second.

Figure 7 shows examples of hoist cable speed determination. This was accomplished by attaching a light mirror and photo cell to the boom. The mirror was fixed to the traction sheave pulley, the light and photo cell to the boom head. As the traction sheave pulley rotates, the mirror will reflect light from the light bulb back to the photo cell once every pulley revolution. When this happens, a little blip is recorded. Thus, the cable speed can be determined by counting the blips per milimeter, and knowing the paper speed, through the equation below:

$$\underset{\text{(in/sec)}}{\text{Cable Speed}} = \text{(Blips/mm)}\ \text{(11.75/Blip)}\ \begin{pmatrix}\text{paper}\\ \text{speed}\end{pmatrix}$$

Note is to be made that the hoist speed varies considerably with different loads. With no load, the speed is 167 ft/min. With 600 pound load, the speed is 86.5 ft/min.

4. Vibration Test - This test was run to determine if helicopter vibration could contribute to cable failure through wear/fatigue (App I, Fig 8). The test was run at 50 cps because the UH-1F vibrational test data indicated that at 50 cps the greatest vibration amplitude (.008 inches) was present. A cable tension of 116 pounds was used because this caused the cable between the inboard pulley and the primary capstan to resonate. The hoist was vibrated for five hours for a total of 900,000 vibrational cycles. A section of cable, including both pulley and capstan tangencies, was taken and broken, using test method 2. The cable broke at 2,900 pounds tension. Three base line samples which had previously been taken broke at 3,510, 3,070, and 3,195 pounds. Thus, there appears to be some minor cable strength degradation but not a significant amount. The hoist functioned perfectly at the completion of the vibration test.

5. Winch Data from Cable Test Winches - A great deal of hoist performance data was generated during the portion of cable testing that involved the use of a hoist. A total of 11,350 cable test hoist cycles was accomplished, including the interim cable test cycles.

As stated in App II, the interim cable testing was accomplished using two winches. The first winch, a used winch from Homestead AFB, had to be replaced after 1,286 cycles because of oil leaks. The replacement winch, an overhauled winch from Breeze, completed the remaining 2,664 cycles of the interim testing. Cable testing continued using this winch.

Three 2,000 cycle tests with a 600 pound load were desired. After 1,400 cycles of the first test, the secondary capstan suffered a structural failure in the spokes of the aluminum casting. This failed the cable. The Homestead AFB winch, which had been repaired at Breeze, was reinstalled and the three 2,000 cycle tests completed. This winch leaked oil but otherwise functioned well.

Thus, discounting the oil leak and the subsequent clutch failure during the interim testing, 7,286 cycles were run on the Homestead AFB hoist without failure. The zero time Breeze hoist ran 4,064 cycles before the catastrophic capstan failure.

6. Boom Structure - During all phases of the testing, hoist structural integrity was monitored visually and by instrumentation. There was no indication of structural overload.

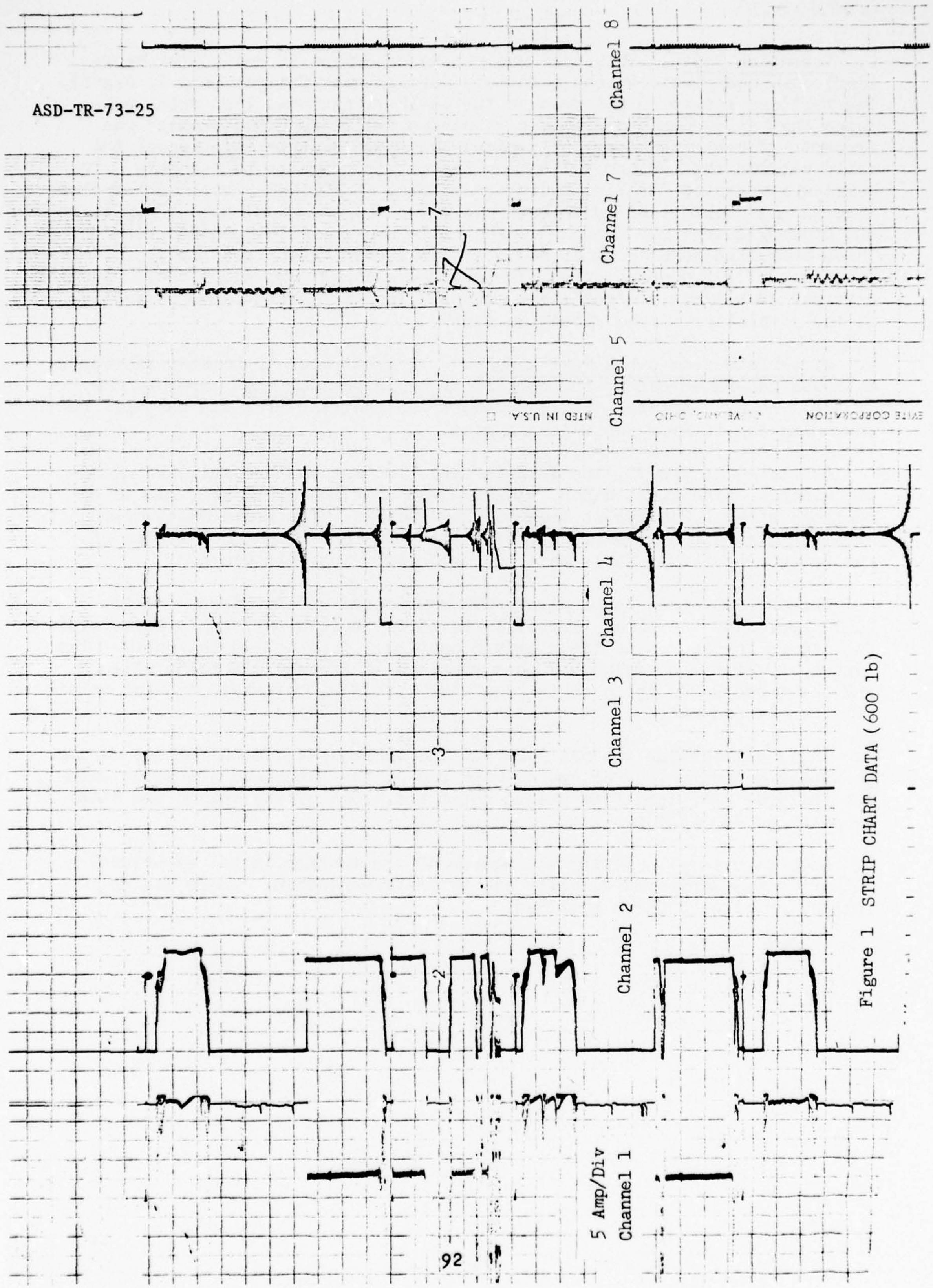

Figure 1 STRIP CHART DATA (600 lb)

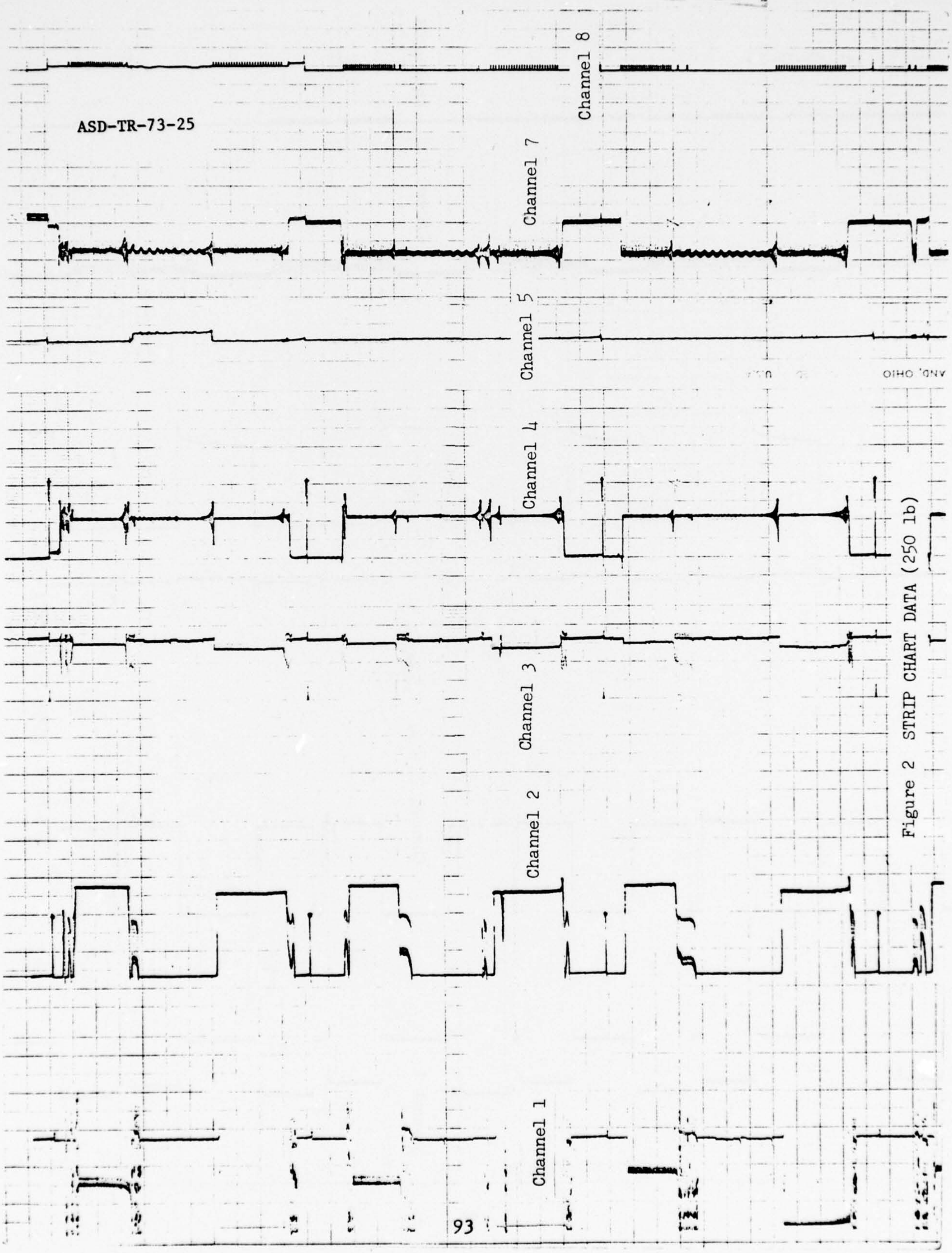

Figure 2 STRIP CHART DATA (250 lb)

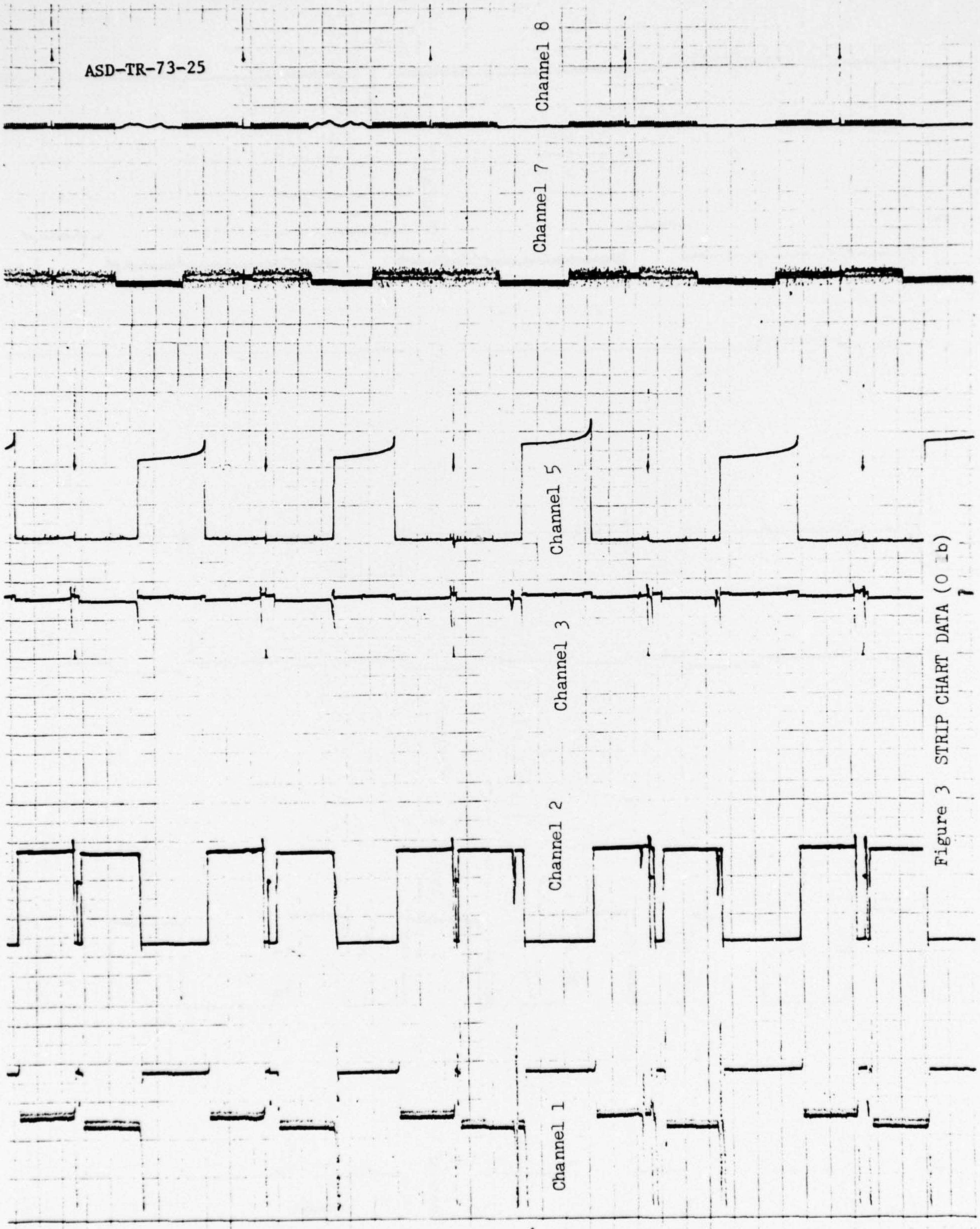

Figure 3 STRIP CHART DATA (0 lb)

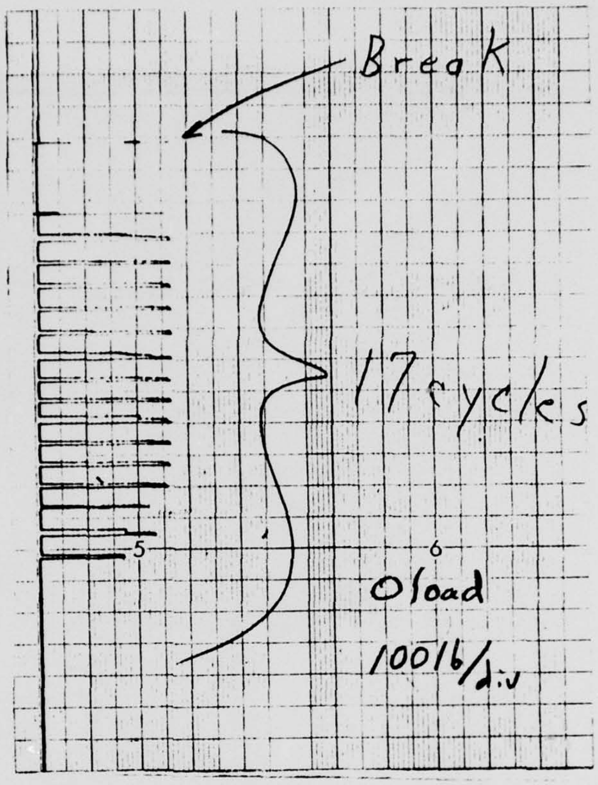

Figure 4 TWO BLOCK CABLE TO FAILURE

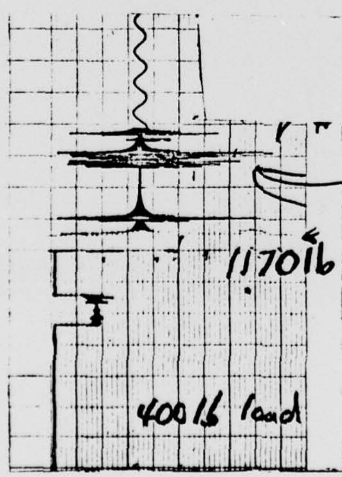

Figure 5 LOAD JOGGING

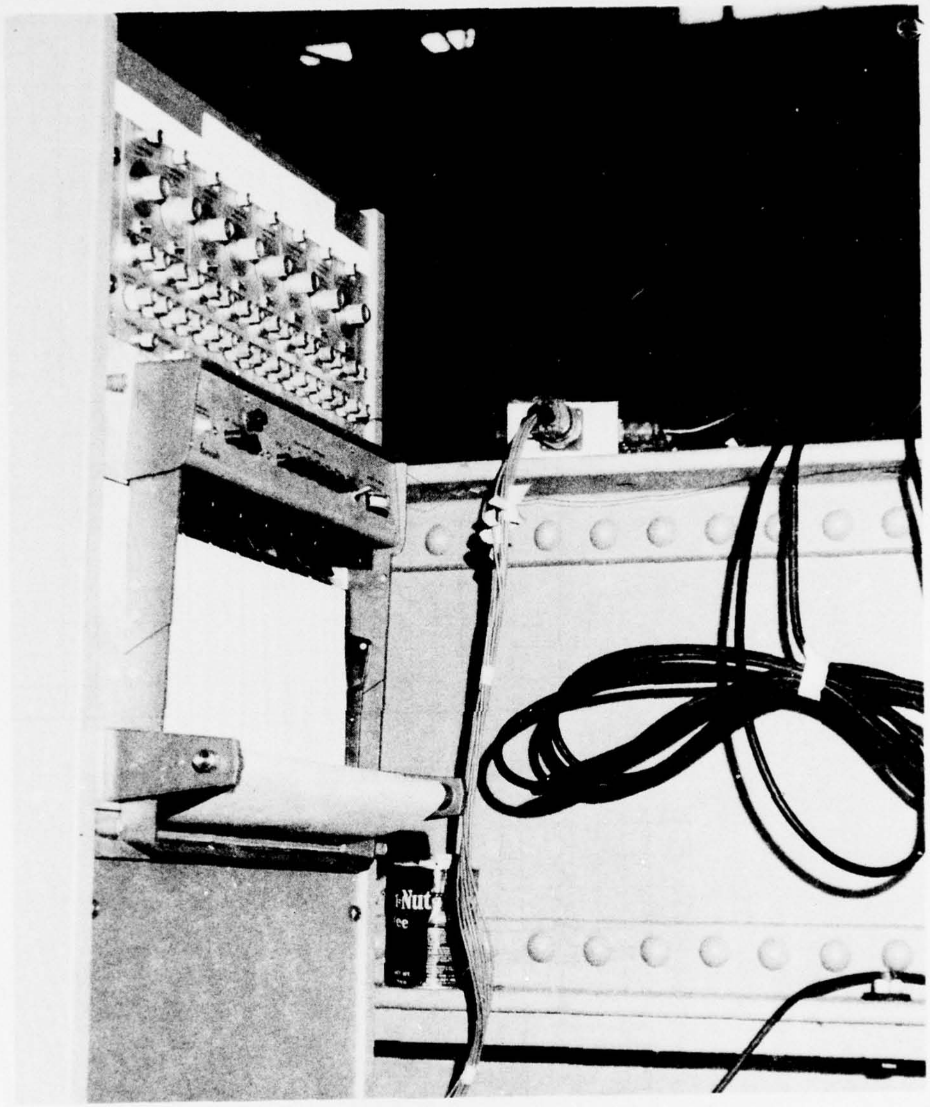

Figure 6 STRIP CHART RECORDER

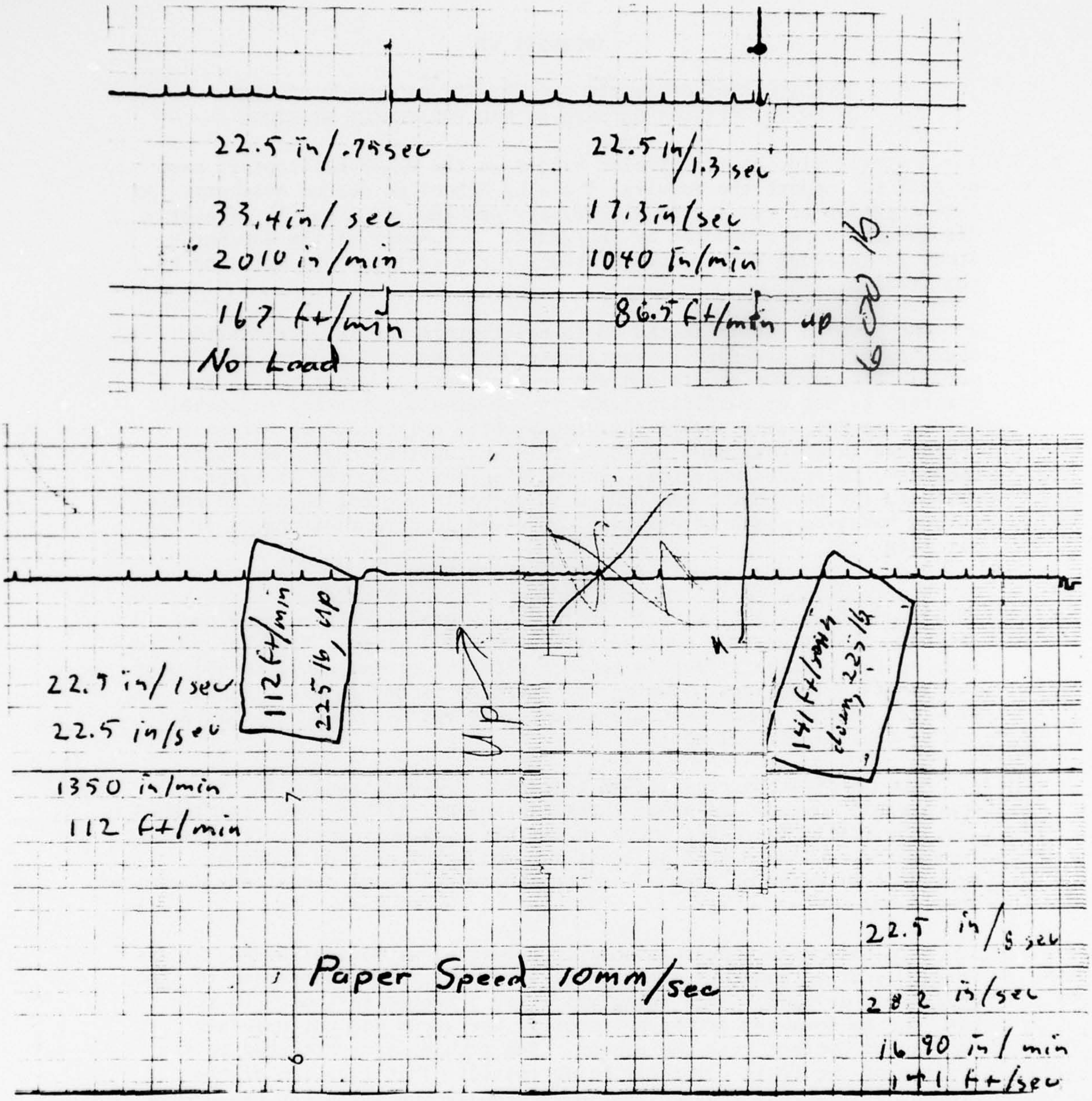

Figure 7 HOIST SPEED DATA

APPENDIX VI

INVESTIGATION OF STATIC ELECTRICITY DISCHARGE PROBLEM
ON UH-1N HELICOPTERS USED BY MAC FOR RESCUE MISSIONS

1. A static electricity problem exists on the UH-1N helicopters used by ARRS to support the Survival Training School on rescue missions. An investigation of the static electricity problem and a review of static dischargers were conducted by ASD/ENVCC. A summary of the ASD/ENVCC study is included with recommendations for a satisfactory solution to the problem.

2. The problem exists on the UH-1N helicopters due to accelerated charging of the aircraft in particular environmental conditions. In normal fair weather conditions the static charge accumulated on the aircraft is not of sufficient capacity to create potential personnel safety hazards. The severe charging problem exists during missions conducted in weather such as snow, rain, or dust which is much more conducive to static charging. During missions conducted in severe weather, the helicopter can charge to potentials great enough to cause severe burns or death to personnel involved in direct discharge of the aircraft.

3. Static discharge is incurred during a rescue mission when the rescue forest penetrator (FP) with the rescuee on board is lifted from the ground. In its present configuration, the FP is raised from the ground leaving the rescuee's feet in contact with the ground until raised past the length of his legs. During this portion of the rescue mission, provided weather conditions are severe, the rescuee is subjected to a substantial electrical shock.

4. From information received in telephone conversations with the operational command and other informed sources, it has been established that the static discharge shock is definitely a personnel safety hazard. The sources indicate that at least two men have received hospital treatment after being exposed to the electrical shock conditions described previously.

5. In a telephone conversation with personnel at Fairchild AFB, it was learned that a temporary solution of a conductive strap dropped to the ground was devised. This strap was first attached to the UH-1N skid, but, due to downwash of the helicopter, the strap did not maintain continuous contact with the ground. The ground strap attached to the bottom of the FP is currently being tested. This location of the grounding strap has reduced the shock problem but the strap has become entangled in the rescuee's leg. Possible problems using this type of fix are obvious. A rescuee could receive the same severe shock should he touch the ground strap before it contacts the ground. The possibility exists of a pickup from a location such that the strap could not contact the ground properly (a mountain side rescue).

6. As a result of an investigation of static discharge techniques by ASD/ENVCC, a number of possible permanent solutions to the static discharge problems have been established. ASD/ENVCC has obtained reports on the operation and testing of various static dischargers. It has been established during various tests that passive static dischargers are inefficient and not sufficient to discharge static electricity in even good weather conditions. The investigation was therefore limited to an examination of active static dischargers.

a. The active static dischargers are well known in aircraft use as a method of reducing the electrical charge on aircraft skin caused by various charging means. Three of the most prominent charging means are ion release from engine exhaust, induction due to earth's electric field, and precipitation static due to charged particle flow over the aircraft. When applied properly, the active static discharger can reduce the stored charge such that no shock by any means will be incurred by personnel.

b. There have been many investigations made on the application of active static dischargers on a large number of different aircraft. The results of these investigations are very conclusive as to the effectiveness of active static dischargers. Each report obtained by ASD/ENVCC concludes that the active static discharger is capable of reducing static charge to the extent that it is no longer a safety problem. However, limitations on test equipment and conditions have restricted the investigations to simulated fair weather testing. As a result, information on the capability of the active static discharger in severe weather conditions is not available.

c. Active static dischargers are installed on HH-53 helicopters but, due to high mechanical failure rates and lack of operator confidence in the devices, they are seldom used. Information received by ASD/ENVCC indicates the active static dischargers are usually not activated during rescue missions for reasons varying from the "possible contact of the high voltage probe with the rescuee" to "they never work anyway."

7. As a result of the ASD/ENVCC investigation, the following recommendations and conclusions are offered:

a. Due to known and possible future use of this rescue helicopter, it is the opinion of ASD/ENVCC that the temporary fix of a forest penetrator ground strap is not adequate. Although this solution is useable, it has serious limitations as previously described.

b. Passive static dischargers are not adequate to perform the task required as helicopter discharger.

c. Active static dischargers appear to be the most adequate and desirable solution. As a result of increasing technology, the basic design of the active discharger is well known. Additional effort must now be expended to increase the capability of the discharger to operate in severe weather conditions and without mechanical failures.

d. There are options open to those interested in utilizing static discharge systems. The US Army Electronics Command (USAEC) is investigating a new technique of static discharging. This involves continuous water spray from the helicopter to ground, acting as a high impedance current path which drains charge from the aircraft. The tests performed by USAEC were on a UH -1C fuselage but were again restricted to fair weather type conditions. Further experimental investigation into this system could possibly provide a very useable discharger for the UH-1N helicopter depending on its capability in severe weather conditions.

e. The ASD/ENVCC recommendation is to utilize an active static discharge system. The decision as to which system to apply should be based on the ability to increase the system capability and reliability for use on the UH-1N helicopter.

8. A file has been established containing current information on static charging and discharging. This information can be obtained from ASD/ENVCC, Wright-Patterson AFB, Ohio - extension 54940.

APPENDIX VII

BACKGROUND

1. US Army History. The UH-1 Internal Rescue Hoist was developed and qualified by Bell Helicopter Company (BHC) in 65 for the US Army. The primary purpose of the hoist was to provide a rescue mission capability for the Army UH-1 series helicopters. It was designed as a lightweight auxiliary piece of equipment which could be rapidly installed and removed as mission requirements dictate. The hoist winch (P/N BL 8300-2) was qualified in Apr 65 by Breeze Corporation, as a vendor to BHC, under specification BER 348. The qualification results, which are contained in BER 338, consisted of various environmental tests and a 1500 cycle life endurance test. Also, a service test of the hoist assembly was accomplished by the Army at Ft Sam Houston during the period 25 Mar through 26 Apr 65. Approximately 70 hoist pick-ups were performed at varying heights and loads (up to 600 lb). The hoist was considered an acceptable piece of equipment for type classification subject to several minor modifications. After incorporation of these changes, the hoist was again tested by the Army at Ft Sam Houston during 11 - 12 Jan 66. About 32 continuous cycles were performed at varying weights and heights. A frayed cable was encountered during an examination of the hoist after test completion. A modification was made to the hoist and the test was repeated at BHC 12 - 16 Feb 66. Twenty-four continuous pick-ups were performed with no problems encountered.

2. USAF History. The rescue hoist was first introduced into the USAF inventory in the Spring of 67 as installed equipment on 26 TH-1Fs delivered to Sheppard AFB, Texas, to support pilot/crew training. Procurement of the hoist was covered by BHC-ECP-287, 15 Apr 66, which offered a "qualified" Army hoist with some added USAF requirements such as a 20-ft caution light on the control box and pilot display panel and a painted cable (20-ft yellow at ball end and 16-ft red at the other end). A TH-1F Configuration Review was held at BHC on 24 Jan 67. Several write-ups (RFSs) were made on the hoist and corrective action taken. The winch was designated as the BL-8300-30. Requalification of this winch was completed by Breeze in Jun 67. The test included a 1500 life cycle test, a high altitude (10,000 ft) pressure test, and a fungus test. All test results were satisfactory. Shortly thereafter, the UH-1P (modified UH-1Fs) helicopters were equipped with hoists obtained from Army and Sheppard assets and deployed to SEA.

a. With the start of the UH-1N program in the Fall of 69, nine hoist kits were procured for the USAF Special Operating Forces (SOF) which, at that time, was the only user of the aircraft. The hoist contained the Breeze winch, P/N BL-8300-31, which added cable guides (bear claws) to the capstan drives. In addition, a new hook was provided and a traction sheave was installed on the end of the hoist boom to assist cable extraction and prevent cable snarls in the boom by maintaining a constant tension of 5-7 lb on the cable as it is being payed off the hoist. In a 22 May 70

letter, MAC advised that they had been allocated some UH-1Ns to support the USAF Survival School at Fairchild AFB, Washington, and there was some question as to whether the hoist was capable of effectively supporting the requirement for 20,000 hoist pick-ups per year (80 hoist operations daily). MAC requested that ASD evaluate the hoist against this projected requirement. In an 8 Jul 70 letter to MAC, ASD/SDQH stated that, based on the contractor data available (including Breeze qualification data), the hoist would support their mission requirements. The two previous 1500 life cycle tests performed by Breeze for the Army and USAF were considered much more severe than the MAC mission profile provided. In addition, field operational experience with the hoist since its introduction in 66 did not indicate any serious problems with the hoist.

b. In a 22 Feb 71 letter, MAC indicated the existence of a potential vertical door clearance problem with the hoist when using some of their recovery devices. They again requested that ASD evaluate this apparent discrepancy and determine if the hoist would satisfy their mission requirements. This letter was followed by another MAC letter, 14 May 71, which questioned our previous approval letter and stated that a motor overheating problem was expected. The letter requested that ASD take ECP action to provide an improved hoist that would safely accomplish their mission requirements and indicated that the HH-1H hydraulic hoist specification would be acceptable. ASD/SDQH letter 5-66, 20 May 71, responded to both of these MAC letters and basically reiterated our previous position that the rescue hoist provided was capable of adequately meeting the mission profile set forth by ARRS. A discussion was also presented concerning door clearance using the "horse collar." It is interesting that up to this point no mention had been made by MAC or ARRS concerning use of the forest penetrator during their survival school support missions. A list of alternatives was provided MAC if the hoist installation was still considered inadequate and it was suggested that, if desired, a firm requirement should be established through the Required Operational Capability (ROC) procedures. At that time no funds were available to support the MAC request for modification.

c. In Jun 71, WRAMA and ARRS requested ASD participation in a program to install UH-1F hoists in the UH-1N. A meeting was held at Hill AFB, Utah, on 29 Jul 71, at which time a prototype installation of the hoist was completed. Approval of the installation was provided by ASD/SDQH message 131307Z Aug 71.

d. On 3 Sep 71, a message was sent to WRAMA requesting that an advisory message be sent to MAC suggesting that they increase the phase inspection interval of the hoist to be consistent with their operations. A detailed inspection of the hoist as part of the basic post-flight (last flight of the day) appeared reasonable. This message was generated after we learned that the survival schools were utilizing the hoists at a rate of 300 to 400 pick-ups per week. At Fairchild AFB, a total of 1160 live pick-ups had been accomplished during a six week period, with approximately 400 additional demonstration and practice pick-ups done during the same period. Per our message, WRAMA took action to revise TO 1H-1(U)N-6 to require this increased maintenance on the hoists at the survival school.

e. On 3 Sep 71, ASD was advised by message ARRS 012110Z Sep 71 of a severed cable incident at Fairchild with a student on board the hoist. Their message also indicated problems with the forest penetrator cocking on the hook, over-temperature of the winch in the low mode speed operation, and clutch burnouts, and requested that ASD investigate the feasibility of installing a hydraulic hoist in lieu of the electrical hoist provided. The incident message was answered by ASD/SDQH message 031621Z Sep 71. The message stated that arrangements had been made with HQ ARRS to airlift the hoist exhibit to BHC for a detailed inspection and that the incident should be considered an isolated case until proven otherwise. This position was taken on the basis that Fairchild AFB had completed more than 1400 pick-ups prior to the incident without any major problems. We recommended that operations at Fairchild AFB be continued under increased inspection requirements until the hoist exhibit could be inspected. On 7 Sep 71, ARRS advised that until the discrepancies associated with the hoist were corrected, the hoist would be restricted to only life or death missions. On 8 Sep 71, a message was received from WRAMA expressing concern with the ARRS message and suggesting that a program be initiated to develop or evaluate a more reliable hoist to support the ARRS mission. These messages were answered by ASD/SDQH message 141329Z Sep 71, which stated that a judgment regarding the suitability of the UH-1N/F hoists to perform the ARRS survival school mission would be made after completion of the Fairchild AFB incident investigation. An additional message was sent, 17 Sep 71, calling a meeting for 23 Sep 71 to discuss the results of our investigation and the corrective action required to eliminate the problem encountered, and also the adequacy of the hoist to meet the ARRS mission.

f. In a 17 Sep 71 message to CSAF/RDQ, MAC requested expedited review of their ROC 10-71 which requested that a new hydraulic hoist be developed for the UH-1N.

g. WRAMA message 161735Z Sep 71 requested authorization to install the BL-8300-4 winch (Army configuration) on the UH-1N. This was required due to insufficient assets to support all USAF UH-1 hoist requirements. WRAMA was advised by ASD/SDQH message 221844Z Sep 71 that the BL-8300-4 winch was satisfactory for use on the UH-1N but warned that this winch did not contain the 20 ft caution light for the cable.

h. The minutes of the 23 Sep 71 meeting are contained in ASD/SDQH letter 9-87, 28 Sep 71. Significant results of that meeting were:

(1) The Fairchild AFB incident was caused by the intermittent operation of an MS relay in the traction sheave which allowed cable slack to form in the winch. This slack resulted in the cable jumping its groove and becoming lodged in the recessed area between the end of the capstan and the housing assembly.

(2) The two winches, which were reported as "burned out," were found satisfactory after a production acceptance check.

(3) A supplementary guard (filler) would be added to the area between the capstan and housing to prevent the cable from becoming lodged in that area.

(4) The wiring in the traction sheave would be changed to provide redundancy in the event a similar type MS relay problem was encountered.

(5) A test program would be done by Breeze to determine the life expectancy of the hoist when subjected to the ARRS mission and whether any operating limitations/restrictions would be required.

(6) Several anti-cocking devices were manufactured locally per a Breeze drawing and sent to Fairchild AFB for test. The device mounted over the eye-bolt on top of the forest penetrator and prevented the hook from cocking on the eye-bolt. No further problems were reported from Fairchild.

(7) WRAMA would take action to update all UH-1F hoists to include the traction sheave.

(8) It was determined that live pick-ups by ARRS would not start until the following actions were completed:

(a) Field retrofit of the ARRS UH-1F hoists with the UH-1N traction sheave.

(b) Breeze examination of additional hoist hardware airlifted to them by ARRS.

i. On 14 Dec 71 the results of the Breeze test program were received. Using the Fairchild AFB mission profile, a total of 2500 cycles was performed. After completion of this endurance test, the hoist was disassembled and inspected. All internal wear was minimal. Motor brush wear was slight. The cable showed wear on the outer wires; however, no broken wires were found and the cable was still considered perfectly useable. The traction sheave showed no severe wear. Based on the testing performed, it was the conclusion of both Breeze and BHC that:

(1) The mission requirements at Fairchild AFB were well within the capabilities of the hoist.

(2) The hoist winch should be overhauled after 10,000 cycles.

(3) The traction sheave lubricant should be changed from grease to dry teflon.

(4) The traction sheave should be overhauled every 2500 cycles.

(5) The control box should be overhauled every second hoist overhaul.

(6) The pendant should be overhauled with the hoist overhaul.

(7) The cable should be replaced after 2500 cycles.

j. In a 14 Apr 72 message, WRAMA was requested to incorporate this overhaul and replacement data by supplement to the appropriate technical manuals. BHC submitted an Urgent Action ECP-652, "Improved Internal Rescue Hoist Assembly." The ECP proposed the following changes to the UH-1N hoist:

(1) Add a cable guard (filler) between the capstan and housing.

(2) Rewire the traction sheave to provide power redundancy.

(3) Seal the adjustable pots on the hoist control box to prevent "field adjustments."

The ECP was approved on 16 Dec 71, with modification to include adding a pip pin to the hook (provide more security) and changing the traction sheave lube to MIL-L-60326 (Fluoro Glide). Three hoists were modified at Breeze and the remaining six were modified by retrofit kits in the field.

k. BHC ECP-663 proposed changes similar to ECP-652 for incorporation into the UH-1F hoists. This ECP has not been approved; however, WRAMA is currently cycling hoist components to Breeze for update to the UH-1N configuration using an overhaul contract. ARRS resumed hoist operations in the latter part of Jan 72.

l. On 28 Mar 72, a severed cable incident was reported from Homestead AFB, Florida, with a student on board. SEA survival School support had been initiated by the ARRS Detachment earlier in the month. As a result of the incident, ARRS again restricted the hoist to only life or death missions until the cause of the incident was found and corrected. The exhibit hoist was airlifted to Breeze for examination. In conjunction with this inspection, a meeting was called at Breeze for 5 Apr 72, among all interested agencies to observe the Breeze effort. The cause of the severed cable was attributed to salt water saturation of the storage drum friction clutch which resulted in clutch slippage. This clutch slippage allowed the inertia of the heavily wrapped storage drum to overcoast in relation to the capstan drive and form a cable loop. The cable loop subsequently traveled over the edge of the drum and wedged between the drum and hoist side frame. The cable was severed at this point. Primary source of the water was the students entering the cabin area. Based on these findings, an ASD message was sent out, 4 Apr 72, restricting the aircraft to a 40 ft minimum hover height over salt water and not allowing SEA survival students to enter the aircraft. In addition, it was recommended that all aircraft at Homestead AFB be closely inspected for salt water damage, especially in the area below the cabin floor. Finally, the message recommended resumption of hoist pick-ups by ARRS under the restrictions cited above.

m. On 11 Apr 72, a meeting was held at ASD to further discuss the Homestead AFB operation. Significant action items were:

(1) A modification was required to prevent water from entering the clutch area. A temporary (interim) fix would consist of a shield or fender over the storage drum. The final fix would be to seal the clutch area. (This ECP is currently under review). Subsequent to the meeting, a prototype fender was fabricated by BHC and tested at Homestead AFB with satisfactory results. However, since there was still concern with the effects of salt spray on the aircraft itself, the restrictions pertaining to 40 ft hover and not allowing students to enter the aircraft were not lifted.

(2) Special inspection and maintenance instructions were developed for the Homestead AFB operation to minimize the effects of the salt water environment.

n. On 14 Apr 72, hoist operations were resumed at Homestead AFB under the guidelines established at the 11 Apr 72 meeting. On 10 May 72, another severed cable incident occurred at Homestead AFB with a student on board the penetrator. ARRS again restricted the hoist to only life and death missions, pending completion of the investigation.

o. The rescue hoist winch (less the boom) was shipped to Breeze for examination. The results of their investigation were inconclusive and argumentative. Consequently, a Hoist Evaluation Task Group was established to conduct a Critical Review of hoist operations at Homestead and Fairchild. The major areas to be investigated included the unexplained Homestead incident, over-all maintenance data and techniques, design suitability, and operational techniques. The team, which was made up of technical personnel from WRAMA, ASD, Breeze, BHC, MAC, and ARRS met at Homestead during the period 23 May through 2 Jun 72. The significant accomplishments of that effort were:

(1) The Homestead severed failure incident was caused by a mis-routed cable in the hoist boom area. The cable was routed over, rather than under, the guide bolt adjacent to the inboard boom pulley (sheave). This was demonstrated twice by actually failing the cable in this manner with the aircraft in a hover and a 300-lb weight on the hook. The appearance of the bolt and cable in each test were identical to that observed from the hoist involved in the incident. Action was immediately taken to perform a one-time inspection of all hoists in the inventory to insure proper cable routing. In addition, tech data were revised to include a caution note in the cable replacement section and a requirement to weight test the hoist after each cable change.

(2) TO 1H-1(U)N-2-1, "Technical Manual for UH-1N Organizational Maintenance," was considered inadequate with respect to hoist maintenance. Action was taken during the meeting to completely rewrite and expand the existing hoist maintenance procedures. The rewrite was provided to ARRS for use pending the issuance of a formal safety supplement to the manual by WRAMA. The supplement was formally issued as Safety Supplement TO 1H-1(U)N-2-1SS-9, 30 Aug 72.

(3) No formal training exists for hoist maintenance personnel. It was agreed that such a training program is required on an expedited basis. ARRS/DOV was assigned as the OPR for this action.

(4) Action was taken to establish a record keeping system (cycle count) for the hoist to determine usage. Also, the need for inspection frequency and replacement criteria for hoist components was established.

(5) Storage, transportation, and handling of the hoist was considered deficient. WRAMA was given the action of designing a fixture or fixtures, including drawings, which would assure adequate support and protection for the hoist in these areas. The fixtures utilized at Fairchild were considered excellent and would be used as models. The Task Group concluded that, with reasonable maintenance and adequate technical data, the UH-1 hoist system could satisfactorily perform both the local base rescue and the survival school training missions. It should be emphasized at this point that this was the second time that all the affected agencies, including the user, agreed that the hoist would meet the ARRS mission requirements. The first time was after completion of the hoist endurance test at Breeze following the first severed cable incident at Fairchild AFB.

p. Live hoist pick-ups were resumed at Homestead on 24 May 72, while the Task Group was present. No significant problems were encountered during this period. It was observed that one of the UH-1F hoists at Homestead did not incorporate a traction sheave. This hoist was not allowed to operate until the hardware was installed. In accordance with a previous request, ARRS issued an advisory message to the field on 7 Jun 72, stating that live hoist pick-ups for training would only be accomplished if the hoist had been updated to the following configuration:

(1) Winch Assembly, P/N BL 8300-32.

(2) Control Box Assembly, P/N BL 8420-11.

(3) Traction Sheave, P/N BL 13800-1.

q. On 2 Jun 72, a supplement was issued to the Flight Manual removing the 40-ft hover restriction over salt water. Guidance was provided as a result of an AFFTC follow-on Category II test effort to investigate the UH-1N salt water spray ingestion problem.

r. On 18 Jul 72, Homestead AFB reported a failed cable in the swaged ball area. The hoist was in the stowed position and the forest penetrator fell on the cabin floor. The cable was airlifted to WRAMA for examination. WRAMA attributed the failure to an overload in excess of 2000 lb. Source of the load was undetermined.

s. In a 27 Jul 72 message, WRAMA issued an Interim Safety Supplement establishing a 1000 cycle retirement schedule for the hoist cable.

t. On 7 Aug 72, Fairchild AFB reported a severed cable incident in which a student received extensive injuries. ARRS immediately restricted all hoist operations to only life or death missions. An ASD technical team was dispatched to Fairchild to assist in the investigation. The cause of the cable failure could not be determined during this on-site investigation so the hoist and cable exhibit were airlifted to BHC for further examination. In a 7 Aug 72 message, ARRS stated that training would not resume until positive corrective actions were taken to provide the safety margin required for their mission requirements. On 14 Aug 72, a safety supplement was issued to the Flight Manual restricting the hoist to only life or death missions.

u. A 16 Aug 72 letter from WRAMA provided the results of their examinations of the Homestead AFB cable (swaged ball area) and subsequent cable sampling from Homestead and Fairchild. Their study tended to show that the cables were in rather poor condition for the number of cycles generated. Of prime importance was the fact that, although the cables appeared visually satisfactory, separation of the cable strands showed significant internal damage. In the same letter, WRAMA requested that ASD conduct a feasibility study in cooperation with the contractor to determine the most expeditious method of providing a cycle counter on the hoist to record usage rates for component TBO and retirement purposes. Both Fairchild and Homestead were using the manual recording method.

v. In a 17 Aug 72 message to all interested agencies, ASD/SDQH established a meeting for 24-25 Aug 72 to discuss the results of the Fairchild incident and determine an appropriate course of action. Specific agenda items were:

(1) A review of past hoist failures and the corrective actions taken.

(2) The status of action items from the Homestead Task Group effort.

(3) ATC hoist training requirements for the survival schools and possible alternatives to actual helicopter pick-ups.

(4) Corrective actions required to return the hoist to operational status.

w. On 18 Aug 72, ASD/SDQH requested ASD/ENYY, by letter, to conduct a Critical Design Review of the hoist to determine if the hoist system could be cost effectively updated to perform safely and reliably all UH-1N missions, or if the hoist should be removed from its assigned missions. On 25 Aug 72, ASD/ENYY, in reply to the ASD/SDQH letter, accepted the responsibility of performing the requested CDR with an anticipated completion date of 30 Nov 72.

x. In continuing review of the hoist problems it was discovered that the hoist cables being examined by WRAMA, BHC, and ASD personnel were not

qualified cables according to MIL-W-83140A, 11 Apr 69. In an 18 Aug 72 message to WRAMA, this discrepancy was pointed out and WRAMA was requested to initiate immediate action to eliminate all unqualified cables from the USAF inventory. They were also advised that, based on test data available, only one cable manufacturer had met the specification requirements. WRAMA complied with this request.

y. To provide additional data for the 24 Aug 72 meeting, contractual arrangements were made to conduct a cable test at Breeze. The primary purpose of the testing was to determine the cable tension resulting from various hook loadings and up-limit switch settings from operative to inoperative. Based on the results from previous cable examinations, there was concern that an inoperative or misadjusted switch could subject the cable to high tension loading.

z. The 24-25 Aug 72 meeting at ASD was very productive and provided a detailed review of the hoist problems encountered. Numerous action items were assigned to various agencies, a majority of which were to support the recently established ASD/ENYY Critical Design Review of the hoist. BHC stated that their analysis of the failed cable from Fairchild indicated that the cable failure was due to a combination of internal wear and repeated high loadings. The cause of these loadings could not be determined. Breeze reported that their examination of the hoist had failed to reveal any contributing deficiency. BHC and Breeze then reported on the cable tension tests performed at Breeze. The test results indicated that, with an inoperative limit switch, the cable could be subjected to loads as high as 2800 lb. Interestingly, the higher loads were observed with minimum weight on the hook, thus indicating that cable speed was a significant factor in inducing these high loads. Both ATC and ARRS expressed deep concern with the continued shut-down of the survival schools and indicated that further delays would certainly involve high level interest. They suggested that the Homestead operation could be resumed with minimal risk since the hoisting was performed over water and the students were only being raised 10 - 15 ft. ATC further stated that, due to SEA and other commitments, the use of H-53 and H-3 aircraft to support the survival schools could not be authorized. They requested that ASD consider removing the present Flight Manual hoist restrictions for the Homestead AFB operation; ASD indicated this could not be done at the present time.

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13. ABSTRACT

This design review was directed at determining adequacy of the UH-1N rescue hoist subsystem and, to an extent, its individual components. Also included was the determination and evaluation of modifications and operational limitations required for safe, reliable future operations. The detailed design review covered the following specific areas: Design analysis for overall subsystem safety and reliability, accelerated testing for interim training clearance, test under laboratory conditions, flight test, and separate wire rope test and evaluation.

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